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Association for the
Advancement
of Science.

Johannesburg 1905
Kimberley 1906

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REPORT

OF THE

journal of science,

SOUTH AFRICAN ~~ASSOCIATION~~

FOR THE

ADVANCEMENT OF SCIENCE.

THIRD MEETING,

JOHANNESBURG, 1905.

FOURTH MEETING,

KIMBERLEY, 1906.

CAPE TOWN:
PUBLISHED BY THE ASSOCIATION.
1907.

Cape Town:
THE ARGUS PRINTING AND PUBLISHING COMPANY, LIMITED.

1907.

EDITORIAL NOTE.

Owing to the visit of the British Association to South Africa in 1905 the usual sectional meetings of the South African Association for the Advancement of Science were not held that year. The proceedings of the Meeting at Johannesburg were limited to the annual business session, and at a later date the President delivered his official address. The Report of the proceedings was issued to Members, in due course, in pamphlet form, but to secure preservation and facilitate reference it is also incorporated with the proceedings of the 1906 Meeting in the present volume.

The individual authors are alone responsible for the statements or opinions advanced in the several papers.

WM. FLINT,
Editor.

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CONSTITUTION OF THE ASSOCIATION.

(As amended at the Third Annual Meeting of Members held at Johannesburg on August the 28th, 1905).

I.—OBJECTS.

The objects of the Association are:—To give a stronger impulse and a more systematic direction to scientific enquiry; to promote the intercourse of Societies and individuals interested in Science in different parts of South Africa; to obtain a more general attention to the objects of pure and applied Science. and the removal of any disadvantages of a public kind which may impede its progress.

II.—MEMBERSHIP.

(*a*) All persons interested in the objects of the Association are eligible for Membership.

(*b*) The Association shall consist of Permanent Members, hereafter called "Members," and temporary Members, elected for a session, hereafter called "Associates."

(*c*) Members and Associates shall be elected directly by the Council, or by the Managing Committee of Council. Associates may also be elected by local Committees. Members may also be elected by a majority of the Members of Council resident in that Centre at which the next ensuing Session is to be held.

(*d*) The Council shall have the power, by a three-fourths vote of those present, to remove the name of anyone whose Membership is no longer desirable in the interests of the Association.

III.—PRIVILEGES OF MEMBERS AND ASSOCIATES.

(*a*) Members shall be eligible for all offices of the Association, and to serve on its Committees, and shall receive *gratuitously* all ordinary publications issued by the Association during the year of their admission, and during the years in which they continue to pay *without intermission* their Annual Subscription.

(*b*) Associates are eligible to serve on the Local Reception Committee, but are not eligible to hold any other office, and they are not entitled to receive gratuitously the publications of the Association.

(*c*) Members may purchase from the Association (for the purpose of completing their sets) any of the Annual Reports of the Association, at a price to be fixed upon by the Council.

IV.—SUBSCRIPTIONS.

(*a*) The Annual Subscription for Members shall be One Pound, payable first at election, and thereafter on the First of July of each year. After the first session* intending Members shall be required to pay an Entrance Fee of One Pound in addition.

(*b*) A Member may at any time become a Life Member by one payment of Ten Pounds, in lieu of future Annual Subscriptions, or in lieu of Entrance Fee and future Annual Subscriptions.

(*c*) The Subscription for Associates for a Session shall be Fifteen Shillings.

(*d*) The Council may authorise Local Committees to admit students as Associates at a reduced subscription on the special circumstances of each case being submitted.

V.—MEETINGS.

The Association shall meet in Session periodically for one week or longer. The place of meeting shall be appointed by the Council as far in advance as possible, and the arrangements for it shall be entrusted to the Local Committee, in conjunction with the Council.

VI.—COUNCIL.

(*a*) The management of the affairs of the Association shall be entrusted to a Council, five to form a quorum.

(*b*) The Council shall consist of all past Presidents of the Association, past and present General Secretaries and Treasurers, and in addition representatives to be elected by each Centre, at a meeting to be held within one month prior to the Annual Meeting of the Association in the proportion of one representative for every 25 Members, and such others to be elected by the Members at the Annual Meeting of the Association, as shall give altogether one Member of Council to every 25 Members of the Association (excluding past Presidents and past and present General Secretaries and Treasurers).

(*c*) The Council so elected shall at once proceed to elect from its Members, the President, four Vice-Presidents, two General Secretaries and one Treasurer. Assistant General Secretaries, and local Honorary Treasurers may be elected at the Annual Meeting, or any ordinary Meeting of the Council. The Council shall have the power to pay for the services of the Assistant General Secretaries, and for such clerical assistance as it may consider necessary.

(*d*) The Council shall have the power to add five Members (if necessary) to its number from among the Members of the Association resident in that Centre at which the next ensuing Session is to be held.

---

* The first session was held in Cape Town from 27th April to 2nd May, 1903.

(*e*) In the event of a vacancy occurring in the Council in the intervals between the Annual Sessions, the Council shall have the power to fill such vacancy.

(*f*) During any Session of the Association the Council shall meet, at least, twice.

(*g*) The Council shall have power to frame Bye-laws to facilitate the practical working of the Association, so long as these Bye-laws are not at variance with the Constitution.

VII.—MANAGING COMMITTEE OF COUNCIL.

In the intervals between the Sessions of the Association, its general affairs shall be managed by a Committee of Council consisting of President, General Treasurer, General Secretaries, and four other Members, elected annually by the Council. Three of the Committee shall form a quorum.

VIII.—LOCAL COMMITTEES.

In the intervals between the Sessions of the Association, its local affairs shall be managed by the Local Committees. This Committee shall consist of the Members of the Council resident in that Centre, with such other Members of the Association as the said Members of Council may elect.

IX.—RECEPTION COMMITTEE.

The Local Committee of the Centre at which the Session is to be held shall form a Reception Committee, to assist in making arrangements for the meeting, and for the reception and entertainment of the visitors.* This Committee shall have power to add to its number from among the Members and Associates of the Association.

X.—HEADQUARTERS.

The Headquarters of the Association shall be in Cape Town.

XI.—FINANCE.

(*a*) The Financial Year shall end on the 30th of June.

(*b*) All sums received for Life Subscriptions and for Entrance Fees shall be invested in the names of three Trustees appointed by the Council, and only the interest arising from such Investment shall be applied to the uses of the Association.

* For arrangements with regard to Papers to be read see Section 14.

(*c*) Subscriptions shall be collected by the Local Honorary Treasurer of each Centre, and by him forwarded to the General Treasurer, after deducting expenditure authorized by the Council.

(*d*) The Local Committees shall not have power to expend money without the authority of the Council, with the exception of the Local Committee of the Centre in which the next ensuing Session is to be held, which shall have the power to expend money collected, or otherwise obtained in that Centre. Such disbursements shall be audited, and the financial statement and the surplus funds forwarded to the General Treasurer at least half-yearly.

(*e*) All cheques shall be signed either by the General Treasurer and a General Secretary, or by the Local Treasurer and Secretary of the Centre at which the next ensuing Session is to be held.

(*f*) Whenever the balance in the hands of the Treasurer shall exceed the sum requisite for the probable or current expenses of the Association, the Council shall invest the excess in the names of the Trustees.

(*g*) The whole of the accounts of the Association, *i.e.*, the local as well as the general accounts, shall be audited annually by an auditor appointed by the Council, and the balance sheet shall be submitted to the Council at the first meeting thereafter, and be printed in the Annual Report of the Association.

XII.—GRANTS FOR RESEARCH.

(*a*) Grants may be made by the Association to Committees or to individuals for the promotion of Scientific research.

(*b*) Committees and individuals to whom grants of money shall be entrusted are required to present to the following Meeting a report of the progress which has been made, together with a statement of the sums which have been expended. Any balance shall be returned to the General Treasurer. In each Committtee the Secretary is the only person entitled to call on the Treasurer for such portions of the sums granted as may from time to time be required. In making grants of money to Committees or to individuals, the Association does not contemplate the payments of personal expenses to the Members, or to individuals.

XIII.—SECTIONS OF THE ASSOCIATION.

The Council shall have the power to constitute such sections of the Association as it may consider necessary. The following sections have been constituted :—

A. Astronomy.
Chemistry.
Mathematics.
Meteorology.
Physics.

B. Anthropology and Ethnology.
Bacteriology.
Botany.
Geography.
Geology and Mineralogy.
Zoology.

C. Agriculture.
Architecture.
Engineering.
Forestry.
Geodesy and Surveying.
Sanitary Science.

D. Archæology.
Education.
Mental Science.
Philology.
Political Economy.
Sociology.
Statistics.

XIV.—SECTIONAL COMMITTEES.

(*a*) The Presidents, Vice-Presidents and Secretaries of the several sections shall be chosen by the Council, after consultation with the Local Committee of the Centre at which the next ensuing Session of the Association is to be held.

(*b*) From the time of their election, which shall take place as soon as possible after the Session of the Association, they shall form themselves into an organising Committee, for the purpose of obtaining information upon Papers likely to be submitted to the Sections, and for the general furtherance of the work of the Sectional Committees. The Sectional Presidents of former years shall be ***ex officio*** members of the Organising Committee.

(*c*) The Sectional Committee shall have power to add to their number from among the Members and Associates of the Association.

(*d*) The Committees of the several Sections shall determine the acceptance of Papers before the beginning of the Session, keeping the General Secretaries informed from time to time of their work. It is therefore desirable, in order to give an opportunity to the Committees of doing justice to the several communications, that each author should prepare an Abstract of his Paper, and he should send it, together with the original Paper, to the Secretary of the Section before which it is to be read, so that it may reach him, at least, a fortnight before the Session.

(*e*) Members may communicate to the Sections the Papers of non-members.

(*f*) The author of any Paper is at liberty to reserve his right of property therein.

(*g*) The Sectional Committees shall meet not later than the first day of the Session in the Rooms of their respective Sections, and prepare the programme for their Sections and forward the same to the General Secretaries for publication.

(*h*) The Council cannot guarantee the insertion of any Report, Paper, or Abstract in the Annual Volume, unless it be handed to the Secretary before the conclusion of the Session.

(*i*) The Sectional Committee shall report to the Council what Reports, Papers or Abstracts it is thought advisable to print, but the final decision shall rest with the Council.

XV.—RESEARCH COMMITTEES.

(*a*) In recommending the appointment of Research Committees, all members of such Committees shall be named, and one of them, who has notified his willingness to accept the office, shall be appointed to act as Secretary. The number of Members appointed to serve on a Research Committee shall be as small as is consistent with its efficient working. Individuals may be recommended to make reports.

(*b*) All recommendations adopted by Sectional Committees shall be forwarded without delay to the Council for consideration and decision.

XVI.—ALTERATION OF RULES.

Any proposed alteration of the Rules

(*a*) Shall be intimated to the Council Six months before the next Session of the Association.

(*b*) Shall be duly considered by the Council,

(*c*) And, if approved, shall be communicated by Circular to the Members of the Association for their consideration.

(*d*) And dealt with at the said Session of the Association.

XVII.—VOTING.

In voting for Members of Council, or on questions connected with Alterations to Rules, absent Members may record their vote in writing.

OFFICERS AND COUNCIL, 1905-6.

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Johannesburg.

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Pretoria.

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SIR CHARLES METCALFE, BART., M.I.C.E.
THEO. REUNERT, M.I.C.E.

Past Hon. Gen. Treasurer :

W. WESTHOFEN.

Assistant General Secretaries :

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FRED. ROWLAND, F.C.I.S., P.O. BOX 1183; 5, CORPORATION BUILDINGS (2ND FLOOR), JOHANNESBURG.
(For Transvaal, Orange River Colony and Natal.)

ADDRESS

By

THEODORE REUNERT, M.Inst.C.E.,

PRESIDENT.

The founding of the South African Association for the Advancement of Science four years ago, in a time of great and almost universal despondency, was an act of faith which has been amply justified by events. A few of its more sanguine promoters ventured to predict that the new Association would supply a want which had long been felt of some means of bringing together men and women from all parts of the country who were keenly interested in its higher destinies: in science, in education, in every kind of intellectual as distinct from merely material progress; that it would lead to friendships which would not otherwise have been formed; that it would serve as a useful channel of communication between Governments or Local Authorities on the one hand, and the various Scientific Societies, besides many disinterested, isolated workers in different branches of investigation and research on the other hand; that it would afford an opportunity for the discussion of many subjects of national importance before a wider audience than had hitherto been possible; and that it would gradually enlist the sympathies of the whole intelligence of South Africa.

Sanguine as these predictions were, they have proved to be not over-sanguine. They have been largely fulfilled already, and are in a fair way towards complete fulfilment. We have held three Annual General Meetings, each more successful than the last, each more largely attended, and more fruitful in the number and range of papers presented. We have published three volumes of respectable dimensions, each of some 500 or 600 pages, two of these containing the proceedings of our first two meetings, and an extra volume on "Science in South Africa," which was specially prepared this year for the use of our guests. It is gratifying in this connection to be able to acknowledge the encouragement and material assistance given us by the several South African Governments. When Sir David Gill, our first President, delivered his inaugural address in Capetown, in April, 1903, the Governor of the Cape Colony graced the meeting by his presence, and the Government of that Colony generously agreed to defray

the entire expense of publishing our first volume, a most pleasing sign of official recognition for so young an Association to receive, and one which the other Governments have acquiesced in following. Last year Lord Milner was with us when our second President, Sir Charles Metcalfe, delivered his address in Johannesburg; and the Transvaal Government not only granted the sum asked for towards publishing our second volume of proceedings, but took the initiative in approaching the other Governments, who jointly provided the funds for our special volume on the present state of science in South Africa. As you were informed by circular, His Excellency the Lieutenant-Governor of the Transvaal, the Hon. Sir Arthur Lawley, had kindly consented to be present this evening. It is a keen disappointment to us all that at the last moment he has been compelled to cancel his engagement, but this disappointment is entirely overshadowed by the grief we feel at permanently losing one whose eloquent advocacy on so many occasions of the cause of science and learning is not the least of the great services he has rendered this Colony.

In addition to the matters mentioned in the annual report, a number of projects have engaged the attention of your Council during the past year, several of which, no doubt, will be regarded as of more than local interest, and well worthy of being made the subject of a whole evening's discourse. Among these are: a Botanic Garden and Arboretum for the Transvaal, to be managed purely as a Government institution; a Forest School for South Africa, which would be the only one in the Eastern Hemisphere dealing with extra-tropical forestry and imparting its instruction in English; a Military College; a system of apprenticeships in connection with continuation and night-schools; the encouragement of nature study and science teaching in schools; a permanent museum for Johannesburg; an annual conference of public librarians and curators of museums, and larger public grants to all such educational institutions; the systematic collection or preservation of objects of scientific and historic interest; the investigation of freshwater fishes and other forms of aquatic life in the interior of the country; a series of memoirs on men of science and other South African worthies; a scheme of university extension lectures; and a Royal Society of South Africa. I mention these matters to show how wide a field is open for your future deliberations, and for all the energies at your disposal.

The year 1905 will always be memorable in the history of South Africa on account of the visit of the British Association. The whole story of the inception of the idea that such a visit was feasible, of the lengthy negotiations which led to its being finally entertained, and of the manner in which, by the co-operation of all classes of the community, that visit was carried out to a final successful issue, will be partly recorded in the next forthcoming annual volume of the British Association's proceedings, but is sure to be further told from many different points of view, in many different languages, in all the various forms of publication, from grave to gay, which the modern Press has devised. I cannot refrain, however, from reading

you the following extract from the "Times" of the 17th October, in which Professor (now Sir George) Darwin gave his impressions of the South African visit on the homeward voyage from Beira, where the Portuguese Authorities, with the grace and heartiness characteristic of the Latin race, fittingly crowned the welcome accorded our distinguished guests by all the other towns and districts of the country.

Professor Darwin says:—"When I accepted nomination to the office of President of the British Association at the meeting to be held in South Africa, I felt doubts as to the value of the scientific work which would be brought before the several sections. The scientific reputation of a sectional President exercises a great influence on the character of the communications which are read before him, and it seemed uncertain whether a sufficiently large number of scientific men of eminence would be able to spare the time needed for so long an expedition. It was therefore with feelings of relief and satisfaction that in the autumn of 1904 and the spring of 1905 I saw our list of presidents gradually filling up with men of the highest scientific rank. When a correspondingly able body of recorders and secretaries was enlisted the success of the meeting was in a great measure secured. In view of the very exceptional character of our meeting unusual pains were taken by the sectional presidents and committees to secure the contribution of important and appropriate papers. The outcome of these preliminary steps was very encouraging, and a full list of promised communications was drawn up. A good many of the papers were contributed by men already resident in South Africa, and by several experts sent on in advance, so that the total contribution to science, especially as applicable to Africa, has proved to be of considerable magnitude. For the present year the South African Association for the Advancement of Science was fused with ourselves, and the preliminary steps which I have explained were taken in consultation with, and by the help of, the President of that Society, Mr. Theodore Reunert, and of other active members. At the special request of our African friends invitations were issued to some fifty foreign men of science of the highest eminence; and, although only a comparatively small number found themselves able to accept, yet the reinforcement of our scientific strength was very great. It may be worth mentioning that there were men from Russia, Finland, Sweden, Germany, Austria, France, Japan, and the United States, and although we were disappointed of a promised Australian contingent, Canada was worthily represented. This is not the place to speak in detail of the large fund, raised principally in the Colonies, for assisted passages to South Africa, of the generous reduction of ocean fares by the Union-Castle Line, of the free railway travel in the several colonies, of the great facilities afforded by the Rhodesian line, or, lastly, but not least, of the truly amazing hospitality, both corporate and individual, extended to us; but enough has been said to show that nothing which could be foreseen was omitted from the preparations. And yet on looking back on our visit I see clearly

that it has in every way surpassed our most sanguine expectations. The rush from day to day during the sessions at Capetown and Johannesburg was so great that it left me but little time for attendance at the sectional meetings. I shall not, therefore, attempt to give any appreciation of the valuable presidential addresses which were delivered, or of the papers which were read. Since Capetown is the seat of the Royal Observatory, and since Sir David Gill's eminence as an astronomer is well known, it was to be expected that the crop of astronomical papers would be large. Moreover, we were fortunate in having among us Dr. Kapteyn, of Groningen, who has collaborated largely with Sir David in the study of the stars of the Southern Hemisphere. Prominent among the papers read were Sir David Gill's account of the survey of South Africa—a scientific enterprise of the first importance—and Dr. Kapteyn's study of the motion of the stars, which seems to give us some insight into what is happening in that vast universe of which our sun is so insignificant a member. Dr. Roberts, of the Native College at Lovedale, gave us an account of his study of double stars carried out in South Africa. This paper was especially interesting to me, since it seems to afford some evidence of the actual efficiency of tidal friction in changing the configuration of a pair of stars even within the lifetime of a man. I am unable to speak at first hand of the work in the biological sections, but I know that in our subsequent journeys the entomologists and botanists found much to interest them, although our visit coincided with the deadest time of the year. The geologists, among whom were Penck, of Vienna, Sollas, of Oxford, and Davis, of Harvard (more properly a geographer), reaped a rich harvest of observation in the geological excursions which filled up the fortnight between the meeting at Capetown and that at Johannesburg. The engineers and chemists must have learned much, and perhaps may have taught a little, at Johannesburg and Kimberley. Finally, I cannot pass over in silence Sir Richard Jebb's very remarkable address at Capetown in the educational section, repeated with some additional matter at Johannesburg. It should be read by all interested in education, whether at home or in Africa. A volume of papers read before the Association which have a special bearing on South Africa is to be printed, and some generous citizens of Johannesburg will defray the incidental expenses. It will, I hope, be found to repay in a measure our debt of gratitude for all the kindness shown us. In conclusion, at the risk of being irrelevant, I cannot refrain from mentioning that I had the pleasure of meeting an old lady, Miss Maclear, daughter of the former Astronomer Royal at the Cape, who had actually seen my father when he was there in 1835. She told me that, as a young girl, she remembers him riding round the Observatory Hill—at that time bare of trees—clad in a white Chilian dress. This is a link with the past that I little expected to find."

Reference was made in the first annual report of your Council to the petition presented to the Transvaal Government for the establishment of an observatory in this neighbourhood. As you are aware,

that petition was very favourably received, and duly acted upon, and the meteorological observatory under the direction of Mr. R. T. A. Innes, on the most commanding position overlooking Johannesburg, has given its name to one of the rising suburbs of this town. Thanks to the liberality of the Bezuidenhout family, the Observatory has secured, at a nominal cost, a site covering ten and a half acres in a situation which can never be obstructed by future building operations. Our belief in the excellence of this site was very strongly confirmed when some of the astronomical members of the British Association met the High Commissioner there on the 30th August last, this party consisting of :—

Sir David Gill, His Majesty's Astronomer at the Cape of Good Hope;
Dr. A. A. Rambaut, Radcliffe Observatory, Oxford;
Mr. A. R. Hinks, Newall Observatory, Cambridge;
Dr. C. J. Joly, Royal Astronomer of Ireland;
Dr. O. Backlund, Director of the Imperial Observatory, Pulkowa;
Professor P. Harzer, Director of the Royal Observatory, Kiel;
Dr. A. S. Donner, The Observatory, Helsingfors;
Professor J. C. Kapteyn, The Astronomical Laboratory, Groningen;
Dr. W. de Sitter, The Astronomical Laboratory, Groningen;
Lord Rosse, K.P., F.R.S., Parsonstown;

who unanimously expressed the opinion that it was one of the finest sites in the world for the erection of a large telescope, both on account of its actual position, and because of the great need of such a telescope in the Southern Hemisphere. Thus, for instance, Professor Kapteyn said :—"In all researches bearing on the construction of the universe of stars, the astronomical problem of the age, the investigator was hindered by our ignorance of the southern heavens. Work was accumulating in the north, which was to a great extent useless, until similar work was done here. He was convinced that the erection of a large telescope here would be of the greatest service to Astronomy generally."

Had time permitted it would have been a grateful task to go over the eleven sections of the British Association in succession, and enumerate the illustrious men representing each branch of science who were among our visitors, as well as to point to the probable practical outcome of the discussions and recommendations of the meetings held, both here and in Capetown, but to do this would be far beyond the limits of a single address. My successor in office will have the pleasant duty, I hope, of reviewing the promised volumes, which are more likely to be three or four than merely the single volume anticipated by Sir George Darwin. This evening I propose to confine myself to reflections suggested by the work done in one of the eleven sections only, namely, that

dealing with education. Fortunately for my purpose, some of the papers read before the Education Section of the British Association in Capetown and Johannesburg have already been published in pamphlet form, including the address of Sir Richard Jebb, the President of the section, which was re-delivered in Johannesburg, with additions bearing on the educational problems of this Colony, before one of the largest audiences that listened to any of the papers or addresses of the whole meeting. This noteworthy gathering was, of course, mainly due to the fame and well-known eloquence of Sir Richard Jebb, and the natural desire of all who were acquainted with his writings to take the opportunity of listening to one of the most brilliant scholars of the day; but it is also largely accounted for by the exceptional interest that is being taken in educational matters at the present time. There is what may almost be described as a wave of enthusiasm for education passing over the country, and it is only natural that the South African Association for the Advancement of Science should eagerly avail itself of so auspicious a moment to concentrate public attention on the educational needs of the country, and on the efforts that are being made in so many different directions to render every branch of education more widespread and more efficient.

As you know, education, in so far as it is equivalent with instruction, consists of three stages: primary or elementary education, secondary or higher education, and the highest or University education. To have gone through these three stages constitutes a liberal education. The great majority of children in this country never get beyond the first stage. They are taught to read and write, generally in one language only, and the merest rudiments of two or three other elementary subjects, such as simple arithmetic, and the outlines of geography and of English and South African history. Time was, within the recollection of many in this room, when even this modicum of education was considered more than enough for what was contemptuously called "the masses." But now, owing to the gradual awakening of the public conscience, and a better understanding of the public interest, any civilised community demands, in the words of the present Lord Mayor of Sheffield, "an open door for every child from infant school to University." Or, to slightly vary the simile, we may regard elementary education as the *key* to knowledge, whilst secondary and University education are successive steps to the *storehouses* of knowledge, to those treasure-chambers enriched with the spoils of time, where the accumulated wit and wisdom of mankind have gathered together the triumphs of philosophy, the marvels of science, and the glories of literature. To all practical intents and purposes access is denied to the bulk of our children to these higher kinds of education. All the more reason, then, why we should make sure that such elementary education as we provide is at least *universally* provided, and the *best* of its kind. A great and increasing effort is being made to ensure this, but as yet we cannot flatter ourselves that the effort is completely successful.

It will probably come as a shock to many to learn that there are *not less than* 50,000 *white children* of school-going age in South Africa who are receiving *no instruction at all.* Until the full official figures of the last general census of 1904 are published in detail, it is not easy to frame even an approximate estimate with any approach to finality. But there is evidence enough to prove that the above appalling number of uncared-for children of European descent—I am not considering the native or coloured population at all for the present—is rather under than over-estimated. That this is so may be shown in various ways.

The preliminary census returns of British South Africa give the total number of the European or white population in the five Colonies, on the 17th April, 1904, as 1,133,756. It is generally assumed that in a properly educated country 1 in 6 of the population should be at school. Thus, in England and Wales, with a population in 1904 of 33,763,434, there were 5,967,868 children on the registers of primary day schools, or a proportion of 1 in 5.7. In Scotland, in the same year, out of a population of 4,627,656, there were on the registers 785,473, or 1 in 5.9. In Ireland, there were 726,552 pupils on the rolls, out of a population of 4,398,462, or 1 in 6. In specially well-educated countries, like Switzerland, for instance, the proportion is as high as 1 in 5. Now, as there are about 1,200,000 white people in the five South African Colonies, if we apply the rule of 1 in 6, it is evident there should be 200,000 children at school. But what are the facts?

In June, 1904, there were only 115,000 pupils enrolled in all the Government or Government-aided schools for white children in South Africa. So that, making the most liberal allowance for children receiving private tuition, and allowing further for the abnormal proportion of unmarried men in districts like the Witwatersrand, the conclusion can hardly be avoided that at least 50,000 white children of school-going age are receiving no schooling at all. Startling as these figures are to those who may have been under the pleasant impression that at least primary education had been successfully dealt with by the State, they are amply corroborated by the recent utterances of the official heads of the several education departments.

In a paper read before the Educational Section of the British Association in Johannesburg, Mr. H. Warre Cornish, late Acting-Director of Education in the Transvaal, stated that of the 300,000 white inhabitants of this Colony at the time of the last census, 145,000 were living in towns and dorps, and that in the rural areas embracing the other half of the population about one-fifth were of school-going age, that is, 30,000 children in the rural districts alone, of whom not more than 10,000 were enrolled in Government schools of the country area, while not more than 5,000 were estimated by Mr. Cornish as receiving education of some kind

in private schools, opened either in competition with the Government, or in the absence of provision by Government. The remainder, he added, are going without education. Thus, in the *rural* areas of the Transvaal alone, 15,000 children are running about wild and untaught; and to these we have to add the untaught children of the towns and villages.

The Director of Education in the Orange River Colony, in his last Annual Report for the year ending June 30th, 1904, states: "As the population of the Colony is about 150,000 whites, there should be about 25,000 children of school age, if we take the proportion as 1 in 6. It is somewhat difficult to know how many pupils attend the private schools which are conducted by the Dutch Reformed Church, or by teachers for private profit; but if we assume the number to be, roughly, 2,000, it means that about 10,000 children are still unprovided with education—a somewhat gloomy prospect to contemplate."

From the 1904 Statistical Year Book for Natal, it appears that out of a total white population of 97,109 there were 16,080 children between the ages of six and fifteen, whilst only 11,338 were enrolled in Government or Government-aided schools, which latter total includes several hundred children above the age of fifteen. In the Natal Report for 1899 (volume 5, page 201, of the Special Reports on Educational Subjects published by the Board of Education, London, in 1901), "it is estimated that about 1,600 children of European parentage are being taught privately or at schools not in receipt of Government aid." Assuming that the increase of privately taught children in the last five years is balanced by the children over fifteen in the above school totals, it would appear that not more than 13,000 children between the ages of six and fifteen are at school, out of a total of 16,000, and that therefore 3,000 white children in Natal of a school-going age are not being taught at all.

The Director of Education in Rhodesia states that, according to the 1904 census, out of a total white population in Southern Rhodesia of 12,623, there were only 1,406 children between the ages of five and fifteen, of whom only one-half were receiving any education, either in Government or private schools.

In the Cape Colony at the last census of 17th April, 1904, out of a total European population of 579,741, there were 120,849 white children of school-going age—that is, between the ages of six and fourteen; but according to the last Annual Report of the Superintendent-General of Education for the year ending 30th June, 1904, there were only 63,434 children on the roll. In this connection, Dr. Muir says:—"In speaking of administration mention must also be made of an extraneous aid which the year has given us, viz., the *Census*. Its value, of course, does not lie in the weight which it lends to the argument for compulsory school attend-

ance; every inspector, every rural clergyman, every school manager knows and feels poignantly the need for such compulsion without having the figures of a census officer before him. The real value of it lies in definitely localising the need, in showing the exact spots where children are running about untaught and uncared for—where school sites and school buildings are wanted—where Government and people have unconsciously conspired to neglect their duty." No accurate figures are available of the number of children being privately taught, but even placing these at the improbable figure of 17,500, it will still leave 40,000 white children in the Cape Colony as yet unprovided with any kind of education.

These figures are further corroborated by official utterances during the recent debate in the Cape Parliament. The Colonial Secretary, who is the Minister charged with the Department of Public Education in the Cape Colony, in moving the second reading of the Compulsory Education Bill on the 15th March, 1905, stated "that there were uneducated—not receiving any instruction at all—between the ages of five and fourteen, 41,334 European children out of a total number of children between these ages of 128,397. One-third of the children who ought to be in school were not in school. Of these 41,334 children 9,792 were engaged in occupations. These were children who were supposed to be necessary to assist in the farming of the country, so that 31,000 were neither employed nor receiving education. Again, of the children who were receiving education, a large number, probably 10,000, were only receiving instruction at home or at Sunday school."

Summarising the above detailed evidence, it would appear that in the Transvaal there are between 15,000 and 25,000 children receiving no sort of instruction whatever; in the Orange River Colony, 10,000; in Natal, 3,000; and in Cape Colony anything from 20,000 to 40,000; which more than confirms the statement that the first rough estimate of 50,000 is rather under than over the mark.

It is unnecessary before such an audience as I am addressing to base any special plea on the facts disclosed by these figures. They are almost too sad for words. That a total of over 50,000 children, who ought to be at school, are going without any kind of education is matter for the gravest national concern. It means, in other words, that not less than twenty-five per cent. of the youth of South Africa are being so heavily handicapped in the race of life that the great majority of them will never have any chance of winning any of its prizes. It also means that many of them will be a permanent embarrassment to the country, and will go to swell the ranks of the unemployed and the shiftless, and to add fresh evidence, if such were needed, of the natural connection that exists between ignorance, pauperism, and crime. It will be said, probably, that the Governments, and especially the Education Departments of the country, are to blame for allowing such a state of things to exist and

continue; but it has to be remembered that governments and departments can only spend the money that is voted them; unless there happens to be a benevolent despotism which pushes on the clock with a firm hand, as was the case in Prussia a hundred years ago under the wise direction of Wilhelm von Humboldt. It is not the Government, but the whole people, who are to blame if they allow one of the very first duties of a civilised community, namely, the providing of elementary education for every boy and girl in the State, to be so imperfectly discharged.

But the shortcomings of our educational system are unhappily not confined to leaving fifty thousand children totally unprovided for. Of the three-fourths of the children of South Africa who are *nominally* at school, a large number are attending school so irregularly that only a very partial benefit can be derived from such education as they are receiving. Anything like normal regular attendance only exists in the higher-class Government schools, and it is probably near the truth to say that at least one day in every week is missed by more than one-half of the children attending schools. Such a result can, of course, not be due in any great measure to unavoidable causes such as illness, but is mainly accounted for by the lax and casual manner in which school work is invariably carried on in countries where attendance is not made compulsory by law. (As an illustration in point, I may mention that a Johannesburg head-mistress told me she was frequently asked to excuse her girls their home lessons, because they had been to the "Empire" the night before.)

It would naturally be expected that the large number of children not attending any school is due to the scattered population in the remoter country districts; but this is not the whole explanation by any means. The two largest towns, one the oldest, and the other one of the youngest, towns in South Africa, are almost equally behindhand in point of primary school attendance, about one-third of the children in both receiving no education at present. Thus Capetown, with 8,015 European children of school-going age, had last year only 4,850 on the rolls; and out of the 12,000 or 15,000 white children in Johannesburg there are still 5,000 unprovided with seats in any kind of school. Wherever we take any fairly large body of children, whether in town or country districts, we find the same state of things; from a third to a fourth of them are receiving no education. This will cause no surprise to those who have looked into the past history of education in other countries. Indeed, that so high a proportion as three-fourths of the children are going to school without compulsion is evidence of exceptional intelligence and keenness for education in the country at large; but it is certainly no reason for neglecting the duty of bringing the remaining fourth within the operation of a school law with as little delay as possible. During the thirty-five years that have elapsed since the passing of the Elementary Education Bill which made primary education compulsory in England, the

percentage of children attending school in Great Britain has more than doubled. It is a pleasant coincidence that the year which witnessed the visit of the British Association should have seen the first successful attempt to introduce the system of compulsory education in South Africa. It was only natural that the Cape Colony, which has always been the pioneer in educational progress in South Africa, should have been the first to take this great step forward. The experiment that is being made there will be watched with the greatest interest and sympathy by all the other Colonies, and it is to be hoped the time is not far distant when it will be possible to have a uniform compulsory education law for the whole country. Of course, there are great difficulties in the way of the universal application of such a law, though the Cape Act removes most of the reasonable objections to it.

By this Act, which was assented to on the 6th June, 1905, provision has been made for the creation of School Boards within every fiscal division of the Cape Colony, two-thirds of the members of such boards being elected by the ratepayers, and the remaining third being appointed by the Governor; a wise reservation which enables representation to be given to the minority in any school district. It is interesting to note that women are not disqualified from being elected members of the school board; and as there are 100,000 girls to educate in South Africa, and 4,000 women teachers in our schools, it is not unreasonable that women should be eligible to sit on school boards.

By Section 51 of the Act it is made the duty of every school board within six months of its constitution to prepare a return of all children of European extraction within its district, "who, being between the ages of six and fourteen, are credibly reported as not attending any public, private, or other school, and as not receiving adequate instruction in their own homes." These returns, when available, will be a most important contribution to the educational statistics of South Africa; and it is ardently to be desired that as soon as possible similar machinery will be devised for collecting equally reliable data in every part of the country.

By Section 60 of the Act it is lawful for any school board, "at any time after the expiry of its first year in office, to resolve to make school attendance compulsory for all children of European parentage or extraction within its district who have completed their seventh, but not their fourteenth, year," and by Section 66 "any person employing a child of European parentage or extraction during school hours who is under fourteen years of age and has not passed the fourth standard," is guilty of an offence against the Act, rendering him liable to a penalty not exceeding forty shillings for each such offence.

By Section 67 it is provided that within "three years after the promulgation of the Act it shall be lawful for the Governor . . . . . . to proclaim in any school district regulations in

regard to compulsory attendance even if no application has been made by the Board for such a proclamation," and by Section 68, "in view of the provision of the preceding section it shall be the duty of the first school board of the district to provide school accommodation before the expiry of its term of office for all such children in its district as may be required in accordance with this Act to be attending school; and it shall be lawful for a school board to incur expenditure for the conveyance to school of children who reside at a greater distance than three miles from the school."

By Section 69 powers are given to a school board under certain conditions to make school attendance compulsory for other than children of European extraction—that is, natives and coloured children.

By Section 72 it is provided that any excess of expenditure over income shall be divided equally between the Education Department out of funds for that purpose voted by Parliament, and the other half shall be met by a special rate, which may be either an owner's rate or an owner's and tenant's rate combined.

Now, as half the white population of South Africa reside at present within the Cape Colony, the working of this first school board Act is bound to exercise a profound influence on the future educational policy of the whole country, and the next four or five years are likely to determine what course it will take, whether it is to be a policy of progress, or one of retrogression. A policy of progress, of course, will aim at keeping children at school much longer than is the average rule at present, and at providing facilities for every promising child continuing his or her education up to the doors of the university, and beyond. Even without knowing anything about the statistics, everyone must have been struck by the early age at which boys and girls leave school in South Africa. In many cases this is presumably done in order that the children may begin to earn wages as soon as possible; in other cases probably owing to sheer ignorance or indifference on the part of their parents. In any case it is a very short-sighted proceeding, even from the lowest economical point of view; for it is almost certain that a boy of 12 or 13 leaving school at that early age in order to go into an office or store, or to work on a farm, will have earned a smaller total sum by the time he is 20, than if he had remained at school a few years longer; whilst for the whole of his subsequent career he is almost inevitably doomed to the least remunerative forms of employment.

It would be a useful work if the South African Association for the Advancement of Science were to compile statistics, as far as obtainable, of the comparative wages earned during successive age periods by different classes of white labour in this country, and to reduce these figures to curves on a diagram (similar to that presented to the American Society of

Mechanical Engineers by Mr. James M. Dodge to illustrate his address on the "Money Value of Technical Training," in December, 1903), and then to publish this information as widely as possible. Secondly, we should organise a campaign in favour of compulsory education, and try to get the minimum age at which children are allowed to leave school gradually raised to 14 or 15, or a corresponding standard. At present only about one in five of all the children in our schools are above Standard IV.; the remainder leave school at such an early age that they have barely learned to read and write, which accounts for the large number of illiterate persons returned by the census.

Educational questions are too often discussed as if they only concerned the children and the general public; but surely there is another class with whose welfare they are even more intimately and permanently connected. I mean, of course, the teachers. There are some 7,000 teachers in South Africa; there ought to be 10,000. I may add, in passing, that I hope to live to see this number enrolled not only on the books of the Education Departments, but in the membership list of your Association; or, what is more important, in some real way associated with us in our work. At the outset, however, it is necessary to draw a distinction between those who are teachers by vocation and those who have merely drifted into teaching. We must remind the latter class that competition is keen in every walk of life, and that to deserve promotion they must be constantly working to keep themselves abreast of the times, and by reading, by study, by throwing their whole heart into their work, they must convince us that it is really their life-work, and then, I am sure, they will find the world not slow to recognise their merit. For, after all, what is there in life that an educated man looks back upon with more gratitude than to the first teachers who lighted the lamp of knowledge and attuned the youthful mind to sympathy with elevated thoughts? And when it happens that the debt we feel so keenly can no longer be repaid to those we owe it to, the most natural thing is to desire to pay it to the younger generation of teachers, whom we, in turn, can help by our sympathy, and in other more practical ways.

It is gratifying to all friends of education to know what good work the normal schools are doing in attracting to the teaching profession a number of young men and young women of South African birth, who in the absence of such facilities would probably have chosen some other career. No effort should be spared to render that profession, which we all theoretically admit to be one of the most honourable and arduous, more attractive still; and I believe the most effective way to do this is not so much in the direction of an increased scale of pay—though, no doubt, that, too, may be needed —as to enhance the dignity of the profession by providing for teachers some prizes commensurate with the prizes which allure the best brains into other professions. Why should there not be a few head-masterships in South Africa equal in

emoluments to, say, a chief-justiceship, and a few school inspectors as well paid as a surveyor-general? Then I would suggest offering what I may describe as a kind of glorified travelling scholarship. After the *Lehrjahre* come the *Wanderjahre;* after the training at the normal school should follow opportunities for travel. I wish it were possible, in the interest of education as much as in that of the teachers, for every deserving teacher of higher rank to have, say, six months' holiday every three years, with a travelling allowance and the necessary introductions to enable them to visit schools in other parts of the world. As things are at present, such visits by the very persons competent to benefit by them are very rarely practicable; for, naturally, when teachers have holidays in vacation time the schools are closed, and under any circumstances it would be unreasonable to expect regular holidays to be devoted to inspecting schools, which could only be done to advantage with a mind unbent from its ordinary work after rest and change. I believe such a scheme as I have outlined is really not half so Utopian as it may sound at the first hearing. I am convinced it would be welcomed with gratitude and enthusiasm, not in this country only, but by teachers in many older lands, and I do not think there is any insuperable financial difficulty about it. In the first place, the government railways in this and other countries would, doubtless, grant free passes, and probably the different steamship companies would issue tickets at reduced fares; for there is no question such a scheme would result in increased traffic by which they would ultimately benefit. The teachers on their return would, of course, deliver lectures on what they had seen, and many of their pupils would want to follow in their footsteps. And in what a different spirit, and with what added force and impressiveness, would these modern pilgrims to the ancient shrines of learning be able to instruct their classes! What extra colour and vividness would they impart to their lessons in geography and history, in the literature and customs of the countries they had visited! I can conceive of nothing more likely to tend to an increase of brotherhood among the nations than such a scheme, by which all the great schools in the world would be united in a league of mutual help and friendly rivalry. Holding very ardently these views, which are, perhaps, not unnatural in the son of a teacher, I may be pardoned for confessing to the glow of delight with which I listened to Sir Richard Jebb's noble words of sympathy with all workers in the cause of education in all its grades, from the lowest to the highest. "The sympathies which they carry with them," said Sir Richard, "are world-wide. As we come to see, more and more clearly, that the highest education is not only a national, but an Imperial, concern, there is a growing desire for interchange of counsels and for active co-operation between the educational institutions of the Colonies and those of the Mother Country."

In one of the best-known English novels there is a memorable description of the havoc wrought in the homes of Anglo-Indians by the cruel necessity of having to send the children to Europe to escape the deadly effects of the climate. What Thackeray so pathetically

described as one of the greatest drawbacks to life in India finds its counterpart in this country, though from a different cause. The climate of South Africa leaves little to be desired; yet owing to the natural desire of parents to give their children the best advantages, many homes are broken up here as soon as the children are old enough to enter an English public school, or in some cases much earlier than this, in order that they may first go to a preparatory school in England. The disintegrating effect of this stern course of action on family and social life has long been recognised as a serious obstacle to the natural steady progress of our towns and villages. It is also liable to permanently estrange many of the more prominent youth of both sexes from the country of their birth. On the other hand, there is much to be said in favour of children being educated in the country where their future career is likely to make them permanent residents. To escape from this dilemma, a middle way has been sought by establishing institutions of the English public school type in this country. The success so far achieved in this direction has encouraged a number of thoughtful and cautious people to recommend the adoption of the system on a more complete and extensive scale. This has naturally evoked the criticism: "Even if you could bring Eton or Harrow or Winchester to South Africa, it would not be the same thing." Of course it would not be the same thing, and perhaps it would not be desirable, even if it were possible. For any institution that has its roots far back in the past is partly nourished by the soil from which it sprung, and cannot be transplanted without losing some of its pristine vigour and grace. The claims of secondary education, however, are so pressing that they must continue to engage the earnest attention of all who are concerned about the future of our children.

Perhaps it is not sufficiently recognised that the English public school has several different types. In addition to the very old schools, there are many of quite recent creation. "King's College of Our Lady of Eton" was established in 1440 by Henry VI., the same monarch who, in the following year, founded King's College, Cambridge, famous for its glorious chapel, probably the most perfectly beautiful interior in the world, of which Wordsworth finely says:

> "Tax not the royal Saint with vain expense,
>
> * * * *
>
> They dreamt not of a perishable home
> Who thus could build."

Winchester is half a century older than Eton, having been founded in 1387; whilst Harrow, as it is well known, dates from the spacious times of Queen Elizabeth—those times of which the educational zeal has been unjustly obscured by their more brilliant achievements in science, art, literature, and discovery. Indeed, the whole of the sixteenth century was remarkable for its enlightened generosity to education. No less than five hundred out of the seven hundred endowed schools that existed in England forty years ago date from

the Tudor period. Henry VIII. founded ten grammar schools, Edward VI. twenty-seven, Mary and Elizabeth between them thirty. But, in addition to the famous old foundations, quite a number of very successful public schools have been founded in England within the last fifty or sixty years. Marlborough, founded in 1843, may be cited as a type of these latter. So that in talking about the possibility of establishing schools in South Africa of the English public school pattern we are not simply proposing to copy what the scornful would call an effete type of the Middle Ages; we are proceeding on lines which, as a matter of fact, many of the most modern educationists still regard as the wisest and safest lines to follow.

Sometimes it is argued that the whole question of higher education should be left in abeyance until the elementary schools have been placed on a satisfactory basis. To those who hold this view it may be replied without much fear of contradiction that primary education is only efficient in countries where university education is widely developed. Thus Scotland, so long and honourably distinguished by its excellent schools, had *four* universities at a time when its population did not exceed the present European population of South Africa, and we have not yet got *one;* the University of the Cape of Good Hope being mainly an examining and degree-giving body. Forty years ago Prussia had seven teaching universities, when England had only three; and Germany has as many more to-day, in addition to the various kinds of technical and other high schools which promote teaching and research work of a university character. There are already several institutions in South Africa entitled to rank in this category, but nearly all of them are suffering from the backward condition of secondary education, and have to form special classes for students who have not yet passed the matriculation examination, and who, properly speaking, ought still to be attending a secondary school. Should we, then, postpone the establishment of one or more teaching universities until secondary education has made greater progress? I am convinced that both undertakings should proceed simultaneously, and I believe the experience of other countries will be found to confirm the wisdom of this course. At the period of Prussia's history to which I have just referred, there were 65,000 pupils in the public higher schools, as against only 15,000 pupils receiving secondary education in England; but then the seven Prussian universities had long been established, and the prosperous condition of the secondary schools in that kingdom was directly attributable to the influence of the universities in setting a high standard of leaving examinations.

In making these comparisons with older countries, we must bear in mind the exceptional racial character of the population of South Africa. I had intended saying something upon the question of native education, but I have trespassed too long on your patience already. I will only remind you that in the State-aided schools of the Cape Colony more than half the children belong to the native

and coloured classes; and that the other Colonies must sooner or later—and the sooner the better—seriously consider what kind of education it is their duty, no less than their interest, to provide for the *four millions* of "other than white" subjects living within their borders. The immediate point I wish to raise, however, is that owing to the large number of native and coloured servants in South Africa, the white population, taken as a whole, are on a *higher plane* than, for instance, the populations of England and Germany; and that, therefore, a larger proportion of the youth of this country will require to be provided with the higher and highest kinds of education. I believe this important point is sometimes overlooked in estimating the number of higher schools and colleges required for our boys and girls. We have seen there are 200,000 white children to be educated in South Africa. Of this total number probably one in ten, ultimately 20,000 children, would avail themselves of secondary education, if it were provided; though at the present time there are probably not 10,000 actually receiving this class of instruction. With 20,000 children to draw into secondary schools, and a total of 10,000 teachers required in all the schools (including those for coloured children) it is quite evident that provision must be made on a liberal scale for the increasing number of students who will require or demand a university training. It is a melancholy fact, but one which cannot be ignored, that of the six or seven thousand teachers in Government or Government aided schools in South Africa, nearly half are uncertificated, while only a minority of the remainder possess a university degree. What we should be most anxious about, however, is not the mere *title* of university, but the quality of the *teaching*. Whether this is given in a college of university rank, or in an institution having the power to confer degrees, is a matter of minor importance. "In considering the question," said Sir Richard Jebb, "of the higher education in South Africa, it is well to remember that the social intercourse of young students, under conditions such as a great residential University might provide, is an instrument of education which nothing else can replace. And it might be added that such social intercourse is also an excellent thing for the teachers."

In some minds the argument for delay takes a slightly different form, and it is asked: Why this untimely haste to provide the most expensive type of education for the rich when the education of the poor has not yet been satisfactorily provided for? Surely, there is a serious fallacy underlying such an argument! A rich man can send his son anywhere he likes in search of the best education the world can offer; the poor man's son must get it at home, or not at all. And who shall venture to say what we may not be losing by delaying to place the highest kind of education within reach of every boy and girl in the land? Nearly all the great men who have made their countries famous by their achievements or discoveries in art, literature, and science, have come from the people; seldom from the well-to-do classes. A hundred names could be cited to prove this; but to take one name only, think of

Carlyle, of whom Professor Tyndall in his Address to the British Association at Belfast said that "far more than any other of his age he aroused whatever of life and nobleness lay latent in its most gifted minds." Carlyle, as all the world knows, was the son of a stone mason. Would "Sartor" or the "French Revolution" have ever been written if there had been no Edinburgh University to open its doors to a poor man's son? It is for the children of the poor that we plead, when we ask for educational facilities in South Africa equal to those of Europe and America. Our boys have already to compete with the best brains in the world, trained in the best schools of the world; as the years go by that competition will become not less but more keen. It is our duty to see them fitly equipped, so that they may hold their own, and rise to be masters instead of servants in the land of their birth. And we want to give them and their sisters something in addition to this, something which only great disinterested centres of teaching impart, some sympathy with the "nobler loves and nobler cares" which spring from a wide knowledge of the past history and aspirations of mankind.

Ten years ago a thoughtful citizen of this town, Mr. H. S. Caldecott, delivered an address on "Our Boys and Girls," which revealed such a callous or ineffective attitude on the part of the State towards one of its most sacred duties, that a number of public-spirited men decided to take the matter into their own hands. The lapse of ten years in the life of a young community like this is a sufficiently long period to be counted as an important milestone in its progress. It is all the more deserving of being recorded since the "Council of Education, Witwatersrand," which was the immediate outcome of Mr. Caldecott's paper, has celebrated its tenth anniversary by setting aside a sum of over £100,000 towards improving secondary and higher education in this Colony, and towards providing opportunities for those young men and young women, whose elementary education has been neglected, to retrieve the disabilities under which they suffer, by means of evening classes and day continuation classes. The moment seems opportune for asking the question: to what extent should the whole burden of education, from the lowest to the highest branches, be borne by the State? I will at once allay the alarm I see on your faces by disclaiming any intention at this late hour of attempting to supply the answer. But as paving the way towards an answer, I may mention the fact that out of the twenty millions sterling expended annually by the four Colonial Governments, less than one million is devoted to education. The proportion of State education to total expenditure in the Orange River Colony in the financial year 1903-4 was 12 per cent., in the Transvaal in 1904-5 nearly 8 per cent., and in each of the two coastal Colonies in the year 1902-3 less than 3 per cent. That does seem to leave some margin for increased education votes, and substantial increases will undoubtedly continue to be voted every year. For purposes of comparison I may add that last year

England spent 8½ per cent. of the total expenditure of £130,000,000 on elementary education alone, and that the Australian Colonies and New Zealand spend from 9 to 10 per cent., as against 5 per cent. being spent in South Africa.

In conclusion, if I have given a somewhat gloomy account of the present position of education in South Africa, perhaps unconsciously darkening the shadows, when there are so many bright and hopeful signs to which your attention might with equal justice have been directed, I trust I may be forgiven for thinking it was more profitable in the short time at my disposal to dwell on the defects of our educational system, rather than on its many undoubted merits. A wise old Scotsman I once knew advised me to take as my motto: "Things are never as good as they look, and never as bad as they look." Much error and discomfort may be avoided by remembering that simple adage. It sums up what poets and philosophers in more ambitious phrase have striven to express for ages. There are two extreme ways of looking at life and its affairs, characteristic of two eternally opposed attitudes of different minds: the melancholy and the sanguine. The Greek poet Hesiod, who was an eloquent exponent of the melancholy view—a kind of primitive Carlyle—has left on record a famous picture of what three thousand years ago he conceived to have been the good old days long antecedent to the iron age into which he lamented to have been born; whereas the enviable mortals of the early world had lived in what Hesiod called the Age of Gold, when greed, strife and want were still unknown—that age which so many poets since his time have vainly sighed to recall. Wiser, and more helpful far, than all these dreamers, is the great poet whom Carlyle was so fond of quoting; two of his sayings have been constantly in my mind during the preparing of this address, and I wish I could find an adequate translation for them. To those who are too easily satisfied with things as they are, Goethe says:—

> "Das Wenige verschwindet leicht dem Blick,
> Der vorwaerts sieht, wie viel noch uebrig bleibt."

(The little we have done fades into insignificance, when we look ahead and see how much remains to be done.)

Whilst to those with backward-turned faces towards the mainly imaginary virtues of the past: that golden age, says Goethe, could indeed be realised "were but men nobler than they are":—

> "Mein Freund, die goldne Zeit ist wohl vorbei:
> Allein die Guten bringen sie zurück";

or in the words of the English poet, who best renders his meaning, and whose writings are a perennial inspiration to all who are striving to make the best ideals of education prevail in the world—Matthew Arnold:—

> "I say: Fear not! Life still
> Leaves human effort scope,
> But, since life teems with ill,
> Nurse no extravagant hope;
> Because thou must not dream, thou need'st not then despair."

OFFICERS AND COUNCIL, 1904-5.

President :

THEODORE REUNERT, M.I.C.E., M.I.M.E.

Vice-Presidents :

Capetown.

THOS. MUIR, C.M.G., LL.D., F.R.S.S., L. & E.

Durban.

JAMES FLETCHER, A.M.I.C.E.

Johannesburg.

SIDNEY J. JENNINGS, M.AMER.I.M.E., M.I.M.M.

Kimberley.

GARDNER F. WILLIAMS.

Members of the Council :

Bloemfontein.

JAMES LYLE, M.A.

Bulawayo.

FRANKLIN WHITE.

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R. MARLOTH, M.A., PH.D.
ARTHUR H. REID, F.R.I.B.A.
W. L. SCLATER, M.A., F.Z.S.
ALBERT WALSH.

East London.

JOHN WOOD.

Grahamstown.

ALEX. EDINGTON, M.D., F.R.S.E.
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GEORGE S. CORSTORPHINE, B.SC., PH.D.
SIR GEORGE FARRAR, D.S.O., M.L.C.
SIR PERCY FITZPATRICK, M.L.C.
FRANK FLOWERS, F.R.G.S.
DAVID GILMOUR, A.M.I.C.E.
DR. F. H. HATCH.
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PROF. JOHN ORR, B.SC., M.I.M.E., A.M.I.C.E.
DR. W. C. C. PAKES.
HOWARD PIM.
A. VON DESSAUER.
ERNEST WILLIAMS, A.M.I.C.E., M.I.M.M.
J. R. WILLIAMS, M.I.M.M., M.AMER.I.M.E., M.I.M.E.

Kimberley.

D. W. GREATBATCH, M.S.A.
THOMAS QUENTRALL, F.G.S., M.I.M.E.

King Williamstown.

H. M. CHUTE, M.R.C.S., L.R.C.P.

Members of the Council—Continued.

Komati Poort.

W. HUTTON.

Lovedale.

ALEX. W. ROBERTS,
D.Sc., F.R.A.S., F.R.S.E.

Pietermaritzburg.

J. W. SHORES, C.M.G., M.I.C.E.
P. A. BARNETT.

Port Elizabeth.

THOS. REEVE.

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J. BURTT-DAVY, F.L.S., F.R.G.S.
H. KYNASTON, M.A., F.G.S.
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Queenstown.

ERNEST E. GALPIN, F.L.S.

Salisbury.

GUY A. K. MARSHALL,
F.Z.S., F.E.S.

Simonstown.

D. MACFARLANE, M.I.C.E.

Stellenbosch.

PROF. J. T. MORRISON, M.A.,
B.Sc., F.R.S.E.. A.M.I.E.E.

Hon. General Secretaries:

J. D. F. GILCHRIST, M.A., B.Sc., Ph.D., Capetown.

WM. CULLEN, Johannesburg.

Hon. General Treasurer:

W. WESTHOFEN, M.I.C.E.

Past Presidents:

Sir DAVID GILL, K.C.B., LL.D., D.Sc., F.R.S., Hon. F.R.S.E.

Sir CHARLES METCALFE, Bart., M.I.C.E.

Assistant General Secretaries:

E. H. JONES, P.O. Box 1497, Capetown.
(For Cape Colony and Rhodesia.)

FRED. ROWLAND (Chartered Secretary), P.O. Box 1183,
5 and 8, Corporation Buildings (2nd Floor), Johannesburg.
(For Transvaal, Orange River Colony and Natal.)

PROCEEDINGS OF THE THIRD ANNUAL GENERAL MEETING OF MEMBERS, HELD AT THE TRANSVAAL TECHNICAL INSTITUTE BUILDINGS, JOHANNESBURG, ON MONDAY, 28TH AUGUST, 1905.

Mr. T. Reunert, the President, occupied the Chair, and there were also present Mr. J. Burtt-Davy, Sir David Gill, Dr. Marloth, Prof. J. A. Wilkinson, Prof. Crawford, Messrs Albert Walsh, Ernest Williams, J. R. Williams, Ababrelton, W. E. Cursons, W. Reid Bell, A. von Dessauer, Dr. J. Hyslop, Rev. Dr. Flint, Prof. J. Orr, Dr. S. Schonland, Dr. J. D. F. Gilchrist, Messrs. R. T. A. Innes, Wm. Cullen, with Fred Rowland and E. H. Jones, Assistant General Secretaries.

The minutes of the previous Annual Meeting were taken as read, and confirmed.

The President explained that the meeting was called to transact purely formal business, and to make provision for the work of the ensuing year. He stated that the report of the Council had not yet been prepared, but he would ask Mr. Cullen to make a brief statement on the work performed by the Council of the Association since the Second Annual Meeting took place.

Mr. W. Cullen referred to the various matters deal with by the Council during the past year, and reported on the progress of the work done by those to whom grants for research work had been made. He also mentioned the part taken by the South African Association in arranging for the visit to South Africa of the British Association; to the appointment of Mr. Goldring as the Association's representative in London; to the work of the Johannesburg centre in inaugurating a Museum in Johannesburg; and the movement they had initiated for starting a Botanical Garden. Mr. Cullen concluded by stating that the report of the Council would be printed with other information, and forwarded to members in due course.

Alterations to Rules.—The Chairman stated that the question of the alterations to the Rules had received the attention and consideration of the Council for nearly a year past, and unless any member present wished to raise any point in connection therewith, he would move that the alterations as printed in the circular sent to members be now adopted. Mr. Cullen seconded, and the motion was agreed to.

Finance.—The Chairman stated that the Treasurer's Report had not yet been printed, but that the financial position of the Association was in a very satisfactory state. The balance on the 30th June, 1905, was about £1,800, out of which they were to pay the British Association £500. A further £400 or £500 would be required for

the purchase of copies of the Report of the British Association's Meeting in South Africa, for presentation to members, and in addition, they hoped to be in a position to make further grants for research work.

1906 *Meeting*.—The Chairman stated that the invitation to hold the meeting next year in Kimberley had been accepted by the Council. The exact date of the meeting had not yet been fixed, but this would be decided as soon as possible.

Presidential Address.—The Chairman stated that he had intended to deliver his Presidential Address that day; but owing to other business this had been found impossible, and he would, therefore, deliver it at some future date.

General Business.—Mr. Reid-Bell proposed a vote of thanks to Mr. Reunert for his services as President during the past year. Mr. von Dessauer seconded. Mr. Ernest Williams and Sir David Gill supported the motion. Sir David Gill referred to the great services rendered by Mr. Reunert in London and in South Africa in connection with the visit of the British Association. The motion was carried unanimously, and Mr. Reunert returned thanks in a few words.

Mr. Ernest Williams proposed a vote of thanks to the Hon. Secretaries, Mr. Cullen and Dr. Gilchrist. This was seconded by Dr. Flint and carried. Mr. Cullen expressed thanks on behalf of himself and Dr. Gilchrist.

Election of Council, 1905-6.—Mr. von Dessauer said that, before proceeding with the election of the Council, he would draw attention to Rule 6 (b), which provided that the meeting could only elect one member of Council to every 25 members of the Association, but that this included ex-officio members, which he thought was not the intention when the rule was framed.

After discussion, the meeting agreed that the correct interpretation of the rule did not mean that Past Presidents, Past and Present General Secretaries and Treasurers should be included in the number to be elected at the Annual Meeting, and the rule was therefore ordered to be further amended accordingly.

The election of the new Council was then proceeded with, at the conclusion of which the meeting closed.

REPORT OF THE COUNCIL FOR THE PERIOD FROM 9TH APRIL, 1904, TO 28TH AUGUST, 1905.

In consequence of the visit of the British Association to South Africa the Third Annual Meeting of the South African Association was limited to the Annual Business Meeting, which was held at Johannesburg.

Although no sectional meetings of the South African Association were held, several members contributed papers to the sectional meetings of the British Association.

The meeting of the British Association was opened at Cape Town on Tuesday, the 15th August, 1905, and was concluded at Johannesburg on Friday, the 1st September, when the work of the Sections terminated.

At the request of the British Association the Council of the South African Association nominated two vice-presidents and two secretaries for each Section of the British Association, to assist the Sectional Committees at Capetown and Johannesburg.

At a meeting of the Council, held on the 26th February, 1904, it was resolved that a handbook on scientific work and progress in South Africa should be published on the occasion of the visit of the British Association to South Africa.

The Editors (Rev. William Flint, D.D., and J. D. F. Gilchrist, M.A., D.Sc., etc.) were appointed by the Colonial Governments on the recommendation of the Council, and the work was prepared under the auspices of the South African Governments and the South African Association for the Advancement of Science, the cost of production being principally defrayed by the various South African Governments.

By arrangement with the British Association, and in consideration of the payment of a sum of £500, the British Association admitted as Associates for the meeting in South Africa all Members of the South African Association for the Advancement of Science who joined the latter Association before the 1st July, 1905, and paid their subscriptions for at least the two years ending 30th June, 1906.

Eight hundred and sixty-two Members elected to become Associates of the British Association on these conditions, and these Members were consequently entitled to attend all meetings of the British Association. They were, however, not allowed to vote at the general meeting of the British Association, and will not receive from the British Association its Report of Proceedings of the meetings in South Africa. The South African Association has, however,

guaranteed to purchase from the British Association, at cost price, copies of this report for presentation to Members of the South African Association who complied with the above conditions.

The Annual General Meeting of Members of the South African Association took place at Johannesburg on Monday, the 28th August, under the presidency of Mr. T. Reunert, M.I.C.E. At this meeting, among other business, Mr. Gardner F. Williams was elected President for 1905-6, with Members of Council and a Managing Committee for the same period. Certain alterations to the Constitution were also adopted.

The Report of the Treasurer for the year ended 30th June, 1905, with financial statements, is appended. With regard to outstanding subscriptions, the names of thirty-one Members, who, in spite of repeated requests, failed to pay their subscriptions for the year ending 30th June, 1902, have been struck off the register.

The Council expresses the hope that Members will not allow their subscriptions to fall in arrear, as besides the trouble and expense caused by the sending out of reminders, the lack of funds prevents the Council from carrying out one of the main objects of the Association, viz., the granting of money for original research work.

The report of the Meeting held at Johannesburg in April, 1904, was published in the following December, and copies have been sent to those who were Members on the 30th June, 1904, and who have paid their subscriptions up to that date. From the appended statement it will be seen that the cost to the Association for printing and distributing the volume has been very small, and the thanks of the Association are due to the Government of the Transvaal for the grant of £400, and to certain gentlemen at Johannesburg who made liberal donations for the same object. Thanks are also due to Mr. W. Cullen and Mr. J. R. Williams, whose services in collecting funds for defraying the cost of publication were so successful.

The list of individuals, societies, and public institutions to which a copy of the report is presented now numbers 158, and at the request of the local committee at Johannesburg the publications received in exchange are sent to Johannesburg for the purpose of forming the nucleus of a scientific reference library there.

The Council has accepted the offer of Mr. A. R. Goldring to furnish information concerning the Association to those who may apply to him in London, and has appointed him as the representative of the Association in London.

The vacancy caused by the resignation of Mr. Henry de Smidt as Trustee has been filled by the appointment of Mr. W. T. Buissinne.

Reports have been received from Mr. J. Burtt Davy, F.L.S., F.R.G.S., that he is making satisfactory progress with the "Annotated Catalogue of the Flowering Plants and Ferns Known to

Occur in the Transvaal," in aid of the preparation of which the Association made him a grant of £50.

Mr. R. T. A. Innes, F.R.A.S., to whom a grant of £25 was made in aid of the work of preparing tables of the barometric pressures over South Africa and adjacent regions is still pursuing his investigations, and will present the final report on his work at the Kimberley Meeting next year.

Professor H. H. W. Pearson, M.A., F.L.S., read an abstract of the result of his researches on *Welwitschia mirabilis* before Section "K" of the British Association during the meeting in South Africa, and the Council has agreed to consider this as a fulfilment of the conditions under which the grant of £25 was made to him.

It will be remembered that in connection with the Session held in Johannesburg in April, 1904, a small Loan Museum was organised. This proved so successful that the Johannesburg Members of Council appointed a Committee to report on the question of a permanent Museum for Johannesburg. The Committee, in order to enlist the sympathy of all classes of the community, and to co-ordinate all interests, approached all the public bodies and scientific and technical societies, with a view to including representatives from each. Nineteen Associations accepted the invitation, and that enlarged committee now consists of thirty-six members under the chairmanship of Mr. Julius Jeppe, with Professor John Orr as hon. secretary. A definite scheme was formulated and pushed forward, but no progress can be made until more funds are available. The Witwatersrand Council of Education has subscribed £100. This Association has lent for preliminary expenses £25, and the Town Council of Johannesburg has promised £1,000 when £5,000 has been subscribed. Gifts of a large number of skins and horns and geological specimens have been made, while a number of valuable models have been lent, which are temporarily housed in the Transvaal Technical Institute Buildings. The Committee, with the assistance of the Johannesburg Reception Committee, organised another Loan Museum in connection with the visit of the British Association, a large number of South African exhibits being shown, which proved very interesting to the oversea and local visitors, over 2,000 of whom visited the collection. It is hoped ere long to realise the aims of the Committee by the organisation of a Museum worthy of the chief mining town in South Africa.

The meeting next year will be held at Kimberley, under the presidency of Mr. Gardner F. Williams, and will open on Monday, the 9th of July.

WM. CULLEN,
J. D. F. GILCHRIST,
Hon. Secretaries.

REPORT BY THE HON. TREASURER FOR THE YEAR ENDED 30TH JUNE, 1905.

During the year 1904-5, the Membership of the Association has largely increased, with a corresponding improvement in the financial position. It is only just to place it on record that such is mainly due to the efforts made by the Officers of the Johannesburg Branch, and to the generosity of the Members and of the general public at that centre in contributing so liberally towards the objects of the Association.

It will be noted that three financial statements are attached :—

(a) One dealing with the income and expenditure of the Association as a whole.

(b) One dealing with those of Cape Colony and Rhodesia.

(c) One dealing with those of Transvaal, Orange River Colony and Natal.

To the latter is appended a separate statement, showing in detail the contributions in aid of the issue of the proceedings of the 1904 Session at Johannesburg and the expenditure in connection therewith.

From the first of these statements, it will be noted that there is a substantial balance to the credit of the Association, but it must be remembered that certain deductions will have to be made, namely :—

(1) Contribution to the funds of the British Association as agreed upon	£500
(2) Life subscriptions and entrance fees... ...	351
	£851

This second item is not lost to the Association, but is not available for ordinary use, being paid over to the Trustees for investment in accordance with Rule 11 of the Constitution.

In accordance with this Rule, a sum of £350 was paid to the credit of the Trustees, and by them placed on deposit in the Standard Bank pending investment on favourable terms.

The total membership on the 30th June, 1905, was 1,289, of which 453 belong to Cape Colony and Rhodesia, and 836 to the Transvaal, Orange River Colony and Natal.

The Life Members number 15 in Cape Colony and Rhodesia, and 6 in Transvaal, Orange River Colony and Natal, or a total of 21.

The arrears of subscriptions still amount to a total sum of £201 for Cape Colony and Rhodesia, and to £221 for Transvaal, Orange River Colony and Natal, or a total of £422.

W. WESTHOFEN,
Hon. Treasurer.

(A.)

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENERAL STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 30TH JUNE, 1905.

RECEIPTS.

To Balance as at 1st July, 1904 :		
Capetown	£270 1 9	
Johannesburg	785 17 3	
	1,055 19 0	
Less Government Grant towards 1904 Report	400 0 0	
		£ 655 19 0
,, Entrance Fees :		
Capetown	61 0 0	
Johannesburg	240 0 0	
		301 0 0
,, Subscriptions—Capetown :		
Life Members	80 0 0	
Associates	3 0 0	
Members	590 10 0	
		673 10 0
,, Subscriptions—Johannesburg :		
Life Members	40 0 0	
Members	599 0 0	
Subscriptions in advance ...	363 0 0	
		1,002 0 0
,, Grants :		
*B.S.A. Co. towards Handbook	50 0 0	
*British Association ...	100 0 0	
Reports Sold	5 10 6	
Excess Commission on Country Cheques	0 17 0	
		156 7 6
		£2,788 16 6

* Received for the specific account named.

EXPENDITURE.

By Salaries	£210 10 0	
,, Printing and Stationery ...	127 16 2	
,, Rent of Hall, Johannesburg ..	21 0 0	
,, General Expenses	128 10 3	
		£ 487 16 5
,, Advances for Scientific Purposes :		
Museum Sub-Committee ...	25 0 0	
Outlays *re* Botanical Gardens	4 15 0	
Grant in aid of Research ...	50 0 0	
		79 15 0
,, Bonus to Editor of Report ..		31 10 0
,, Placed on Fixed Deposit ...		350 0 0
,, Deficit Balance, Johannesburg : Proceedings Account, as per Appendix		6 15 6
,, Cash in hand on 30th June, 1905 :		
*Capetown	1,018 17 7	
Johannesburg	814 2 0	
		† 1,832 19 7
		£2,788 16 6

* For details of this amount, part of which is held in trust, see statement "B.

† In addition to the £350 on fixed deposit, a sum of £351 (Entrance Fees and Life Subscriptions), which is included in the amount shown as cash in hand on 30th June, 1905, will be transferred to an Endowment Fund Account.

I certify that the foregoing Account has been prepared from the duly audited Capetown and Johannesburg Statements.

J. M. P. MUIRHEAD, F.S.A.A., F.C.I.S., etc., Auditor,
Incorporated Accountant.

Capetown, 22nd August, 1905.

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDED 30TH JUNE, 1905.

(CAPE COLONY AND RHODESIA.)

RECEIPTS.

To Cash in hand 1st July, 1904 ...		£ 270 1 9
,, Entrance Fees		61 0 0
,, Subscriptions—		
Life Members	£ 80 0 0	
Members, year 1901-2 ...	1 10 0	
,, ,, 1902-3 ...	18 0 0	
,, ,, 1903-4 ...	85 0 0	
,, ,, 1904-5 ...	295 0 0	
,, ,, 1905-6 ...	191 0 0	
Associates, 1903 Meeting ...	1 10 0	
,, 1904 Meeting ...	1 10 0	
		673 10 0
,, Remittance by Treasurer at Johannesburg for investment	508 0 0	
,, Sale of Annual Reports ...	3 0 0	
,, Excess Commission on Country cheques	0 17 0	
		511 17 0
,, Amounts placed temporarily to credit of the Association A/c—		
(a) Contribution towards expenses of Central Organising Committee for British Association	100 0 0	
(b) Grant towards Handbook "Science in South Africa"...	50 0 0	
		150 0 0
		£1,666 8 9

EXPENDITURE.

By Salaries	£100 0 0	
,, Printing and Stationery ...	36 16 8	
,, Postage	16 18 2	
,, Cables and Telegrams ...	5 13 4	
,, Cost of distributing the Report of the 1903 Meeting ...	47 9 0	
,, Sundries	9 4 0	
,, Bonus to Editor of 1903 Report	31 10 0	
,, Grant to Mr. J. Burtt-Davy for Research Work	50 0 0	
,, Placed on Fixed Deposit ...	350 0 0	
		£647 11 2
,, Cash in hand on 30th June, 1905	890 17 1	
,, Amount due (after deducting disbursements made) to:—		
(a) Central Organising Committee for British Association	79 4 6	
(b) For Handbook "Science in South Africa"	48 16 0	
		1,018 17 7
		£1,666 8 9

Audited and found correct.

J. M. P. MUIRHEAD, F.S.A.A., F.C.I.S., etc., Auditor,
Incorporated Accountant.

Capetown, 4th August, 1905.

(C.)

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 30TH JUNE, 1905.

(TRANSVAAL, ORANGE RIVER COLONY AND NATAL.)

RECEIPTS.

To Balance as at 1st July, 1904 ...	£785 17 3	
Less Government Grant towards 1904 Report ...	400 0 0	
		£385 17 3
,, Life Members' Subscriptions...	40 0 0	
,, Entrance Fees	240 0 0	
		280 0 0
,, Subscriptions	595 0 0	
,, Arrears, 1903-4	4 0 0	
		599 0 0
,, Subscriptions in advance ...		363 0 0
,, Sale of 1903 Reports ...		2 10 6
		£1,630 7 9

EXPENDITURE.

By Remitted Capetown		£508 0 0
,, Advances for Scientific Purposes :		
Museum Sub-Committee ...	£25 0 0	
Outlays *re* Botanical Gardens	4 15 0	
		29 15 0
,, Sundry Expenditure :		
Salaries	110 10 0	
Printing and Stationery ...	60 11 2	
Rent of Hall, 1904 Meeting ...	21 0 0	
Petty Expenses	79 14 1	
		271 15 3
,, Balance (Deficit) of Proceedings Account, 1904, as per Appendix		6 15 6
,, Cash on Hand		814 2 0
		£1,630 7 9

Examined and found correct.

HOWARD PIM, F.C.A.,
Hon. Auditor.

Johannesburg, 26th August, 1905.

Appendix.

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

STATEMENT SHOWING FINANCIAL POSITION AS REGARDS VOLUME OF PROCEEDINGS ACCOUNT, 1904, AS AT 30TH JUNE, 1905.

REVENUE.

To Government Grant	£400 0 0		
,, H. Eckstein & Co.	225 0 0		
,, Consolidated Goldfields ...	125 0 0		
,, Premier Diamond Mining Co.	110 10 0		
,, General Mining and Finance Corporation	100 0 0		
,, Goerz & Co...	50 0 0		
,, Anglo-French Exploration Co.	50 0 0		
,, Farrar Bros.	50 0 0		
,, Chamber of Mines	50 0 0		
,, S. Neumann & Co.	50 0 0		
,, Johannesburg Consolidated Investment Co.	25 0 0		
,, Witwatersrand Council of Education	25 0 0		
,, Barnato Bros.	25 0 0		
,, B. Kitzinger	25 0 0		
,, Fraser & Chalmers	10 0 0		
,, Julius Jeppe, Esq.	5 0 0		
,, Max Langermann, Esq. ...	5 0 0		
,, Receipts from 3 Volumes sold	1 11 0		
		£1,332 1 0	
,, Balance (deficit)		6 15 6	
		£1,338 16 6	

EXPENDITURE.

By Argus Printing and Publishing Co., Printing Account ...	£1,282 19 0	
,, Star Billposting Co., Delivery of Copies and Addressing ...	42 0 0	
,, R. Gardiner, Compiling Index	5 0 0	
,, Postages on Exchange Volumes	8 17 6	
		£1,338 16 6
		£1,338 16 6

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PRESIDENT'S ADDRESS.

1—ADDRESS.

By Gardner F. Williams, M.A.,

President.

When your Council did me the honour of asking me to accept the presidency of the Association for this year I had not made any definite plans for the future, but I outlined what might happen and which has since taken place, namely, that I would shortly take up my residence either in England or America.

With this information before the Council I was elected your President. I appreciate the honour conferred upon me, but at the same time I have to express my regret that I am unable to be present on the occasion of your visit to Kimberley where I spent so many years endeavouring to make the De Beers Company one of the most successful mining enterprises in the world. I feel certain, however, that your meeting will be a great success, and that the Association will be accorded a welcome characteristic of the citizens of the Diamond Fields, and of the great corporation which has done so much for the benefit of all who reside there.

I propose to give short historic sketches of the settlement of the Cape, of the adventurous spirit of the Portuguese, of the influence of the Dutch Pioneers, who, year after year, trekked farther north until they occupied the country from the Cape to the Limpopo, and of the rush of adventurers from almost every part of the world who laid the foundation of the mining industry of to-day.

There were two motives for exploration that so signally stamped the fifteenth century—the riches of a new world and an all sea route to India.

Somewhere in the unknown expanse of Africa, tradition placed the land of Ophir and King Solomon's mines, and the explorer knew of the coming of the Queen of Sheba to the King followed by a great train loaded with gold and precious stones. The finding of the southern waterway to the Indies was the first reward of the daring explorers, Dias and Da Gama.

Subsequently Da Gama touched at Mozambique (1st March, 1498) and saw gold in the hands of the Arabs that had passed up the coast from Sofala, which was one of the traditional gateways to King Solomon's mines. Here the Portuguese built a fort which they called Ophir, and made this the starting point of adventurers in search of the fountain of King Solomon's treasures.

These expeditions were continued by the Portuguese with little result until the Dutch and English began to tread upon their heels in the beginning of the seventeenth century.

About the middle of the century Jan van Riebeek, a man of ardent spirit and uncommon energy, landed at the Cape of Good Hope. He seems to have had great confidence in the traditions of Monomotapa, and it is known that he had before him books infused with the romance of Africa. He plotted the location of Davaque, the chief seat of the splendours of Monomotapa at a point 828 miles N.E. of the Cape of Good Hope, and 322 miles W. from the Indian Ocean, curiously near the present Witwatersrand. Nearer still to the Cape, tradition placed another El Dorado, the city of Vigiti Magna, which was located on or near the 30° 11′ of south latitude, and not much more than 300 miles from the Cape.

As the Cape became settled by the Dutch, expedition after expedition was sent out in search of these mythical cities, only to return without any tidings of good cheer to the founders of the colony.

Abraham Gabbema led the first little party into the unknown land north of Fort Good Hope, to be followed by the expeditions of Danckerk and Cruythof and Meerhoff and Everaert and de la Guerre. One notable undertaking was the despatch of a party of expert assayers and miners from the Netherland to Cape Town in 1669 by the Dutch East Indian Company, with instructions to search for any promising outcrops of ore in the region of the Cape. This party prospected for several years, but saw nothing to inspire them with the hope of finding King Solomon's mines.

A revival of the dazzling old visions came in 1681, with the appearance at the Cape of a party of Namaquas bearing pieces of rich copper ore.

This exhibit spurred the East India Company to send out another expedition ; Simon van der Stel was then Commandant at the Cape. He was quick to despatch a company of thirty soldiers, a draughtsman and a reporter to make the venture so often tried in vain by others. Again, after months of struggle, the desert drove them back. Van der Stel, nothing daunted by these continued failures, formed an expedition of 42 white men with Hottentot servants and guides. Olaf Bergh was put in command, and led his company on to Namaqualand. But it was the same old story. No strength of men or oxen availed against the desert where no rain had fallen for twelve months, and the whole region was an arid waste without a trickle of moisture.

In the following year Izaac Schuyver pushed over the desert a little farther than Bergh, and brought back a sack of copper ore. As a last resort the unflinching Van der Stel resolved to head an exploring party himself. The preparations for this expedition were in keeping with the dignity of his position as the head of the Dutch settlement at the Cape.

He left the castle of Good Hope August 25th, 1685, with fifty-six white followers and a troop of Hottentot attendants. He

was more favoured than others who had attempted to penetrate the dark continent. The time of year chosen for the start was precisely the same as for Bergh's expedition two years before, but the difference in the face of the country was amazing. After the long drought heavy rains had fallen. Grass was growing everywhere, and the water courses which had been dry so long were full to overflowing.

As the expedition advanced it found rich croppings of copper in a range lying a little below the 30° 11′ of south latitude. Van der Stel had reached the line of the supposed location of the golden city of Vigiti Magna. He followed this line to the Atlantic, but saw no trace of the traditional city or of the realm of Monomotapa.

After months of travel, this notable exploring party came back to the Cape. It had found rich copper ore in Namaqualand, but the deposits were too far from the Cape to be of any immediate value. These copper mines have been worked since 1853, and have produced copper to the value of £11,000,000. Van der Stel had pricked the bubble of Vigiti Magna and the myth of the realm of Monomotapa was practically dead.

So the credulous search for Ophir came to an end, and for more than one hundred and fifty years there was little life in the tradition of King Solomon's mines.

About the middle of the last century search for the mines of King Solomon was again commenced. The expeditions of Carl Mauch, Adan Renders, Hartley, Baines and Nelson, and later explorers are well known to most of you.

A precise and graphic study of the ancient structures in Mashonaland was made in 1891-92 by Theodore Bent and his associates in the expedition promoted by the Royal Geographical Society, the Chartered Company and the British Association for the Advancement of Science.

Bent saw in the ancient ruins and workings "evidence of a cult known to Arabia and Phoenicia alike, temples built on accurate mathematical principles, containing kindred objects of art, methods of producing gold known to have been employed in the ancient world and evidence of a vast population devoted to the mining of gold."

The main conclusions summarized by Professor Keane are strongly backed by others. Ophir was not a source of gold, but its distributor, as the port on the south coast of Arabia through which the flow of gold came by sea. Havilah (Rhodesia) was the land whence came the gold of Ophir.

Dr. Theal, South Africa's greatest historian, has given this subject much thought and study, and his conclusions are that "the influences responsible for the oldest gold mines and the oldest buildings in what is now called Rhodesia, emanated from South Arabia, but that there were other Asiatic influences, especially from western India."

From the earliest settlement of the Cape by the Dutch there had been a slow but continuous advancement to the north. Year after year the pioneers pushed out farther into the interior, settling upon

the choice locations where there was sufficient water for their stock. It was soon discovered that there were large tracts of land, unsuited to agriculture, which would serve as ranges for cattle and sheep. A little hut of wattle and daub sheltered the family of the pioneer farmer. These settlers were phlegmatic and peaceful by nature. An extraordinary impulse was needed to convert them into adventurers and wanderers in the desert. This impulse was given by the capture of the Cape by the English, by the influx of immigrants from Great Britain, by new and vexing legislation, and by disasters to crops when thousands of farmers were ruined and brought even to the verge of starvation.

There was a succession of vexations to the old colonists. The substitution of English for Dutch was a great humiliation. But the keenest resentment was excited by the emancipation of the slaves in 1833. Alien rule was the grievance which was the impelling cause of the exodus of the Dutch from Cape Colony called the Great Trek.

This migration of pioneer Boers in large parties, overcoming all mountains and deserts, and fearlessly venturing into the strongholds of the fiercest native tribes, undoubtedly hastened and secured the possession of the marvellous diamond and gold fields of South Africa.

The history of the Zulu race is familiar to all. By their raids and wars, the whole country from the seaboard of Natal nearly to the junction of the Orange and Vaal rivers, was desolated, and the native tribes inhabiting this region were almost annihilated. The push of the migrating Boers soon brought them in conflict with Umsilikazi and Dingaan Then their remarkable traits stood out in high relief. In the heart of the wilderness in his venturesome trek over the pathless veld, and in the traverse of mountains and deserts, the Boer showed what scornful eyes had not seen—the self-reliance, the fortitude and the pluck of the true pioneer. Even the women and children were dauntless at the pinch of need. No impediments nor dangers stayed the advance of these pioneers. No Karroo was so forbidding and no stream so swollen as to stop their onward march. Their faith in the literal inspiration of the Bible was unwavering. The clash between the trekking Boers and the impis of Umsilikazi and Dingaan came at last. Umsilikazi was beaten back with enormous loss, and driven in flight to the wilderness beyond the Limpopo, where he brought together the remnants of his people in the present Matabeleland.

Hard upon the defeat of Umsilikazi came the greater clash with Dingaan, who had treacherously put to death a party of sixty Boers who had entered Natal. The battle of Blood River, when six hundred mounted Boers under the command of Andries Pretorius, withstood the attack of many thousand Zulus, was the turning point in the history of South Africa. Three thousand six hundred Zulus were left dead on the field. It is related in history that this decisive victory was gained without the loss of a single life to the Boers. Dingaan fled into Swaziland, where he was put to death by one of the Swazi chiefs.

So the Boers finally stayed the sweep of the Zulu scourge which had laid waste a great stretch of land north of the Cape settlements. Since the first expeditions scores of roving hunters had chased their game over a network of devious tracks, traversing every nook of the land between the Orange and the Vaal, and often camping for days upon their banks. Then the trekking farmers plodded on after the hunters, sprinkling their huts and kraals over the face of the country, but naturally squatting first on the arable lands and grazing ground nearest to water courses.

The defeat of the hordes of savages had made it possible for these pioneers to live in safety along the Orange, Vaal and Caledon Rivers.

For years Dutch and English traders, hunters, pioneers, farmers, shepherds, and missionaries trekked heedlessly over these African beds without picking up a diamond. There is nothing surprising in this. No spot in a diamond field has any resemblance to a jeweller's show tray. Hardly a person in all South Africa had ever seen a rough diamond. The roving hunters were looking for game bounding over the veld, and gave no heed to the pebble-strewn bank. The stolid Boer pioneers would hardly bend their backs to pick up the prettiest stone that lay upon the banks of an African river.

The discovery of diamonds was the reward of daring adventurers and stubborn pioneers who had pushed into the heart of the dark continent.

A poor farmer's child found a pebble on a river bank, carried it home and dropped it with a handful of other pebbles on the farmhouse floor. One little white pebble was so sparkling in the sunlight that it caught the eye of the Boer's wife.

The story of how a Dutch neighbour, van Niekerk, obtained possession of the stone and handed it to the trader, John O'Reilly, of how it was passed on to Lorenzo Boyes, then Civil Commissioner at Colesberg, and finally reached Dr. Atherstone at Grahamstown, has been told too often to be repeated here.

For more than a year after the discovery of the first diamond there had been a desultory search for diamonds in the gravel along the banks of the Orange and Vaal rivers. The first systematic digging was begun by a party of prospectors from Natal. This was the forerunner of the second Great Trek to the Vaal from the Cape, to be followed by thousands of adventurers from all parts of the world. Nearly all were without experiences in mining of any kind.

The advent of Australians and Californians experienced in placer mining for gold was of great service in conducting the search for diamonds. The men composing this influx were largely of English descent, but men from every part of South Africa joined in the rush, and nearly every nation in Europe was represented.

No laboured recital can compass and picture in print any approach to the instant impress on the eye and ear of the moving drama on the banks of the Vaal. It was a mushroom growth of a

seething mining camp in the heart of the pasture lands of South Africa.

Outside of the Indian and Brazilian fields no considerable supply of diamonds had been discovered anywhere. Some diamond-bearing gravel had been found in Borneo, which yielded a small return, and in 1829 Humboldt and Rose discovered the first diamond in the gold placer field of the Ural Mountains. In Bohemia, Australia, Mexico and the United States, the picking up of a few isolated specimens was noted as a curious occurrence.

So at the time of the discovery of diamonds on the banks of the Vaal River, there were no known methods for the extraction of diamonds beyond the shovel of the Indian, the batea of the Brazilian, or the cradle of the gold miner.

As the discovery became known, a motley throng of fortune-hunters began to pour into the valley of the Vaal. It is doubtful if a single one of this fever-stricken company had ever seen a diamond field, or had the slightest experience in rough diamond winning, but no chilling doubt of themselves or their luck restrained them from rushing to their fancied Golconda. Many were as bitterly disappointed by the rugged stretch of gravel at Klip-drift as the gay Portuguese cavaliers were at the sight of the Manica gold placers.

Prospecting for diamonds was going on not only upon the river banks, but also upon many of the farms on the high veld.

Diamonds are said to have been found on the farm Jagersfontein even earlier than the memorable stone which was found on the bank of the Orange River. Whether this be true or not, it is a well-known fact that a large diamond was found on this farm in August, 1870. In the following month diamonds were found at or near du Toit's pan. Early in 1871 diamonds were unearthed close to the farmhouse of Bultfontein, to be followed during the first days of May by the discovery of diamonds on de Beer's farm, Vooruitzigt. Two months later a second diamond bed was uncovered on the same farm.

So within a year, August, 1870 to July, 1871, the Jagersfontein mine and the Dutoitspan, Bultfontein, De Beers and Kimberley mines were discovered in succession.

But who could calculate, or even pretend to predict with any assurance, the prospect of fortune in this African wonderland, so phenomenal in character and so slightly explored ? Here was a strange, luring beacon in the heart of traditional Ophir where river banks were apparently lined with diamonds, where diamonds were strewn on the face of farms. Who would not rush to a region so sparkling in promise, where another Koh-i-nur might be lying in wait in the dust for the first passer-by, and where a lucky adventurer might stuff his pockets with gems far surpassing the hoard of any nabob ?

I need not tell you of the privations and sufferings and disappointments of the first swarm of prospectors along the banks of the Vaal River, nor repeat the history of the rise of the diamond mining industry. Many of you were among the pioneers of the early days. Credit is due, however, to these pioneers for the change which came

over the dismal face of South Africa, until then an almost unknown and unexplored wilderness.

There must always be some strong incentive to cause men to leave comfortable homes, and brave every danger to seek fortunes in remote parts of the world.

The discovery of gold in California led thousands upon thousands of daring adventurers to that country, there to settle and become the backbone of its future prosperity, which, in a few years, depended less upon its output of gold than upon its agriculture, its commerce, and its industries. So, too, Australia, at first a purely mining country, has grown year by year to be less dependent upon its mineral resources.

If Dame fortune was slow to reward the search for King Solomon's mines and the gold of Ophir, she at last revealed to the light of the world pits more dazzling than the glittering stones of fire in the inaccessible valley which the great Alexander beheld, and richer than the soil that Sinbad the Sailor found "which was of diamond, the stone wherewith they pierce minerals and precious stones—whereon neither iron or hardhead has effect."

Nor did Dame Fortune stop with her display of diamonds. Following this revelation came another even more astounding. In the unknown expanse of Africa tradition, as has been told, had placed King Solomon's mines and the marvels of Ophir. For centuries men had braved strange perils to reach these mines, but their labours remained unrewarded until, by chance, the marvellous discovery of gold on the Witwatersrand, made possible by the pluck of brave men, who tore the wilderness from the clutch of the lion and beat back the impis of Tschaka, Dingaan and Umsilikazi, was made known. Here were mines richer than King Solomon's, waiting the coming of men from the new Golconda, men of courage and enterprise and ability ; men with brains that were capable of great conceptions and great performances.

By the discovery of the diamond mines in Griqualand West, the exports of South Africa have been increased by nearly £90,000,000, and the gold mines of the Rand, discovered in 1886, have swelled this great exhibit of mineral wealth by the addition of gold already aggregating over £140,000,000.

I cannot do better than to repeat here the substance of the remarks I made upon the eve of my departure from Kimberley in December last. Farming is to-day the backbone of several countries which a few years ago depended solely upon their mines for resources.

Here in South Africa farming is carried on under great difficulties. Able engineers are required to plan and build reservoirs to conserve the water which flows in torrents for a few hours and then leaves the crops to wither in an almost tropical sun before there is another downpour. It will require the combined energy of the scientists and the farmer to rid the country of the various diseases which make cattle and horse raising so precarious, and of the locusts and other pests which make the raising of crops even more uncertain.

What has been done in other countries can be done here, but it will require the combined energy of the people to accomplish it.

I would urge you to bear in mind that the prosperity of South Africa does not depend alone on its mineral wealth ; while these enormous productions are being taken out of the earth, we, as an Association, must not be unmindful of our duty to the country at large.

As Cobden remarked on the future greatness of Manchester, " just in proportion as mental development goes forward, and in proportion to the development of wealth and mental resources, just in the same proportion will our destiny be exalted, or the very reverse."

While you are devoting your time to scientific research, to technical work in connection with the great mining enterprises, and to various other pursuits, do not neglect the intellectual training of the young men and women of the country, for upon them the future prosperity of South Africa will depend.

The struggle for existence has become so acute that the man who does not use his brains to assist him in his work is left far behind those who have had proper education and training. It is the duty of an Association like this, the influence of which is far-reaching, to do all in its power to improve the educational facilities, so that the youth of these colonies may be given opportunities for higher mental training.

Before closing my address, I beg leave again to express my regret that I am prevented from being with you on this occasion, and to thank the members of the Council for the honour they have conferred upon me.

SECTION A.

Astronomy, Chemistry and Metallurgy, Mathematics, Meteorology, Physics.

Section A.

PRESIDENT'S ADDRESS.

2.—THE DIURNAL VARIATION OF BAROMETRIC PRESSURE.

By J. R. Sutton, M.A., F.R.Met.S.

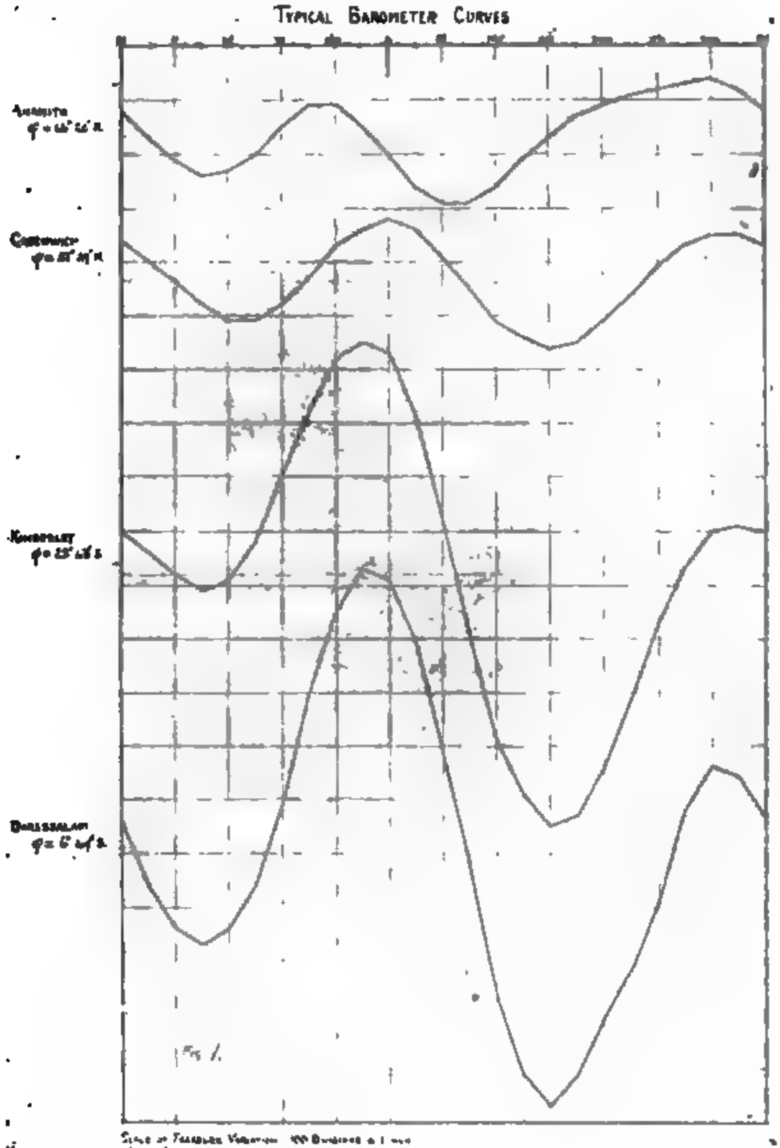
The present occasion is unique in my experience, inasmuch as it is the first scientific meeting I have ever personally addressed. I have contributed occasional papers to scientific societies, it is true, but in every case I have had to depend upon some friend to read them for me. You will see from this that the South African Association for the Advancement of Science is scarcely to be congratulated upon its President of Section A. If a moral may be drawn from the situation, it is that it is a mistake to expect every town which entertains the Association to provide Presidents and Sectional Officers. You would have got a President with more experience, and altogether better suited to the position, by selecting officers on their merits, and not on account of where they live. Any little inconvenience incurred by appointing officers not in residence would be more than counterbalanced by their suitability.

Another reason for quarrelling with my position here is that I am not qualified to pass in review, according to orthodox tradition, the present state of the sciences comprised in this section. My topic has necessarily to be special, confined to one branch of study; if I were to attempt more I should be speaking of things concerning which some of my hearers would know more than I do.

With this preface I have to ask for some forbearance and attention while I bring before you some aspects of the fundamental problem in Meteorology (one might almost say the fundamental problem in Geo-Physics): the semidiurnal oscillation of the barometer. The case is this: All over the world, on land and sea, in valleys and on mountains, the barometer rises and falls twice a day, the maxima of pressure coming in general before Noon and before midnight, the minima a few hours before sunrise and before sunset respectively. It will be convenient to denote these in the following way :—

m_1, the early morning minimum;
M_1, the morning maximum;
m_2, the afternoon minimum; and
M_2, the evening maximum.

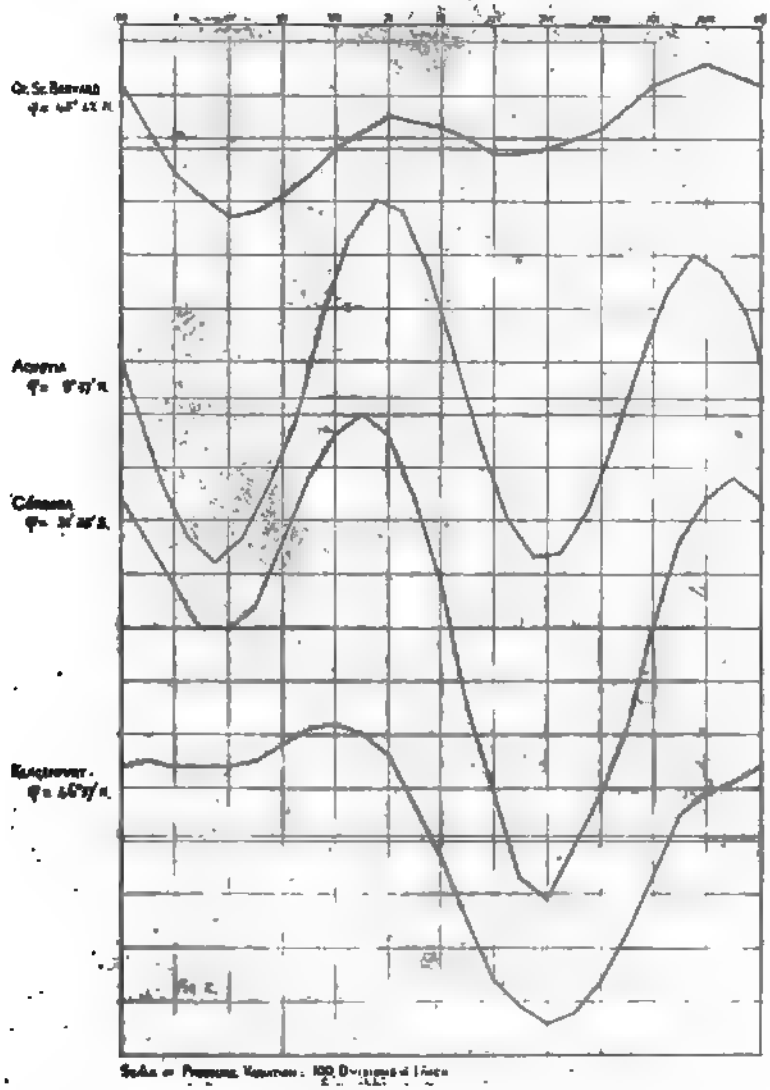
Some typical specimens of the diurnal variation of the barometer shewing these phases are given in Figs. 1. and 2. We see from these



that the mean annual range of the diurnal variation of the barometer decreases from the equator to the poles with some differences in the

epochs of the maxima and minima, and in the shapes of the curves. Generally speaking, for all places situated on open continental plains, the night variation (i.e., from M_2 to m_1) is small, as at

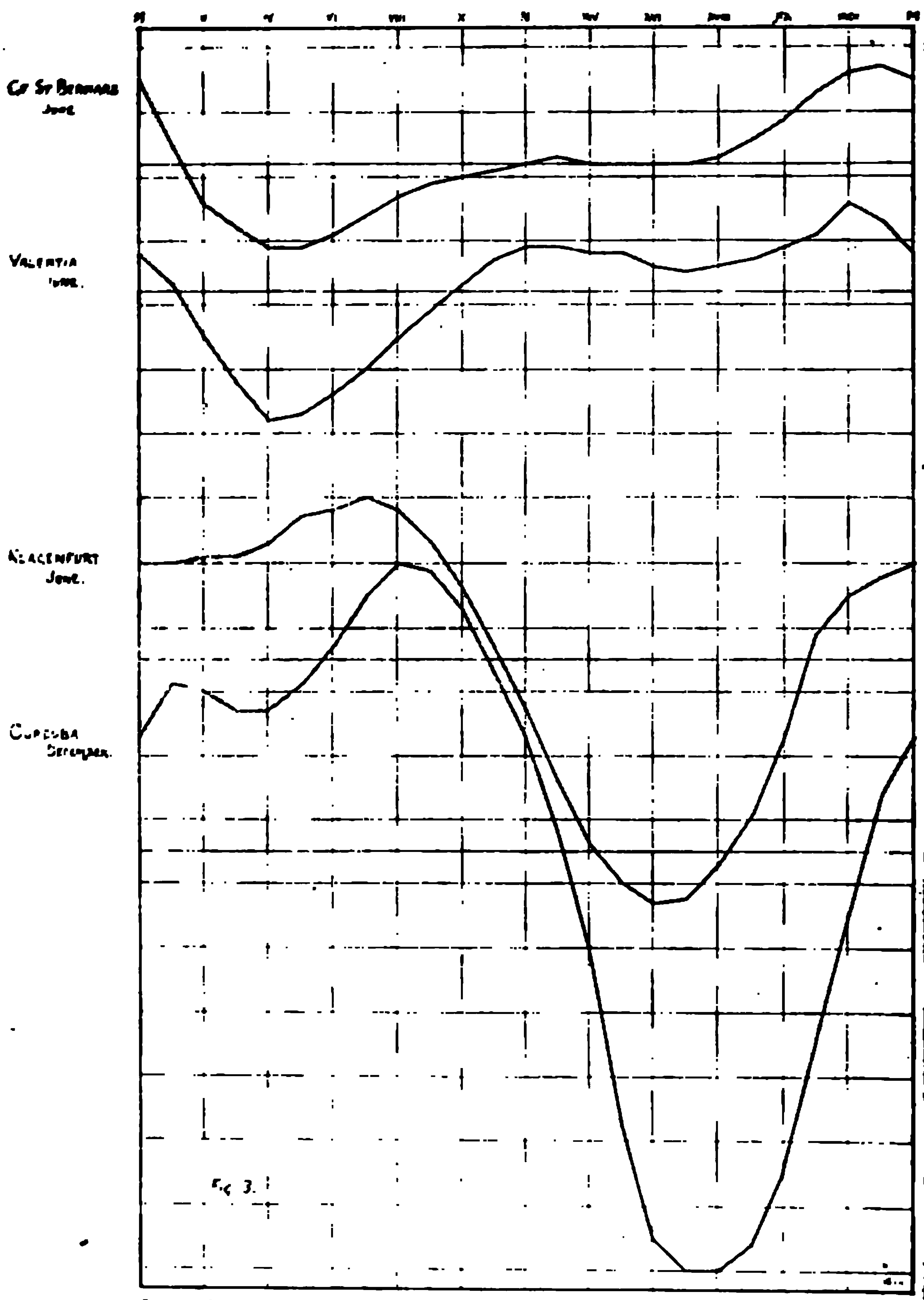
TYPICAL BAROMETER CURVES.



Kimberley; and much greater for maritime situations, such as Greenwich and Daressalam. Also on, or near, mountain summits such as Agustia (6,200 feet), and Great St. Bernard (8,100 feet), m_1

as deep as or deeper than m_2, while in deep valleys m_1 may be of no great depth, as at Córdoba, or abortive, as at Klagenfurt in the

SUMMER BAROMETER CURVES.



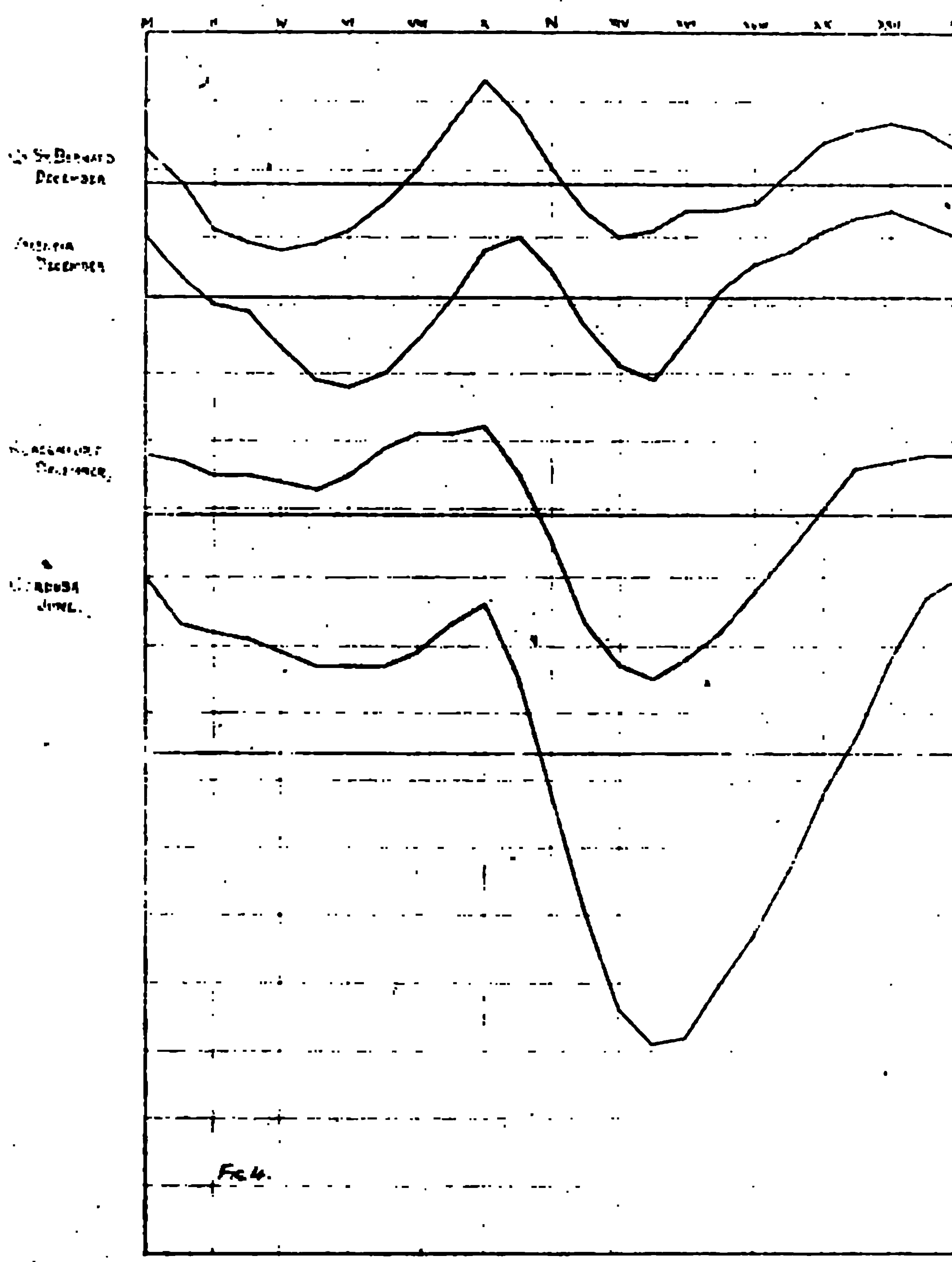
Scale of Pressure Variation 100 Divisions = 1 inch

Alps, and m_2 very pronounced, as compared with stations on the level in the same latitude. Thus, for example, from M_1 to m_2 at

Greenwich is ·024 inch, whereas the corresponding range at Klagenfurt is ·054 inch.

The actual epochs of the maxima and minima vary between moderate limits, and so also do the gradients. The second maximum

WINTER BAROMETER CURVES



SCALE OF PRESSURE VARIATIONS 100 DIVISIONS = 1 INCH.

is not, anywhere, far from 10 or 11 o'clock in the evening, and varies to no great extent throughout the year. In the summer, however, in the case of deep valleys, the early morning minimum tends to vanish (Fig. 3), and hence the second maximum tends to extend itself

into the first, which is, on the whole, over the earth's surface generally, nearly half a day later. This fact is strikingly shewn throughout the summer at Klagenfurt, and is also plain enough at Córdoba. The first maximum, on the other hand, varies largely, averaging 8 a.m. at Klagenfurt, 9 a.m. at Córdoba and Kimberley, 10 a.m. at Greenwich and Agustia, 11 a.m. at some places in the west of Europe, and later still on some mountain summits in the north temperate zone. Also as the seasons vary, the time of the morning maximum at any one station will vary. Thus at Kimberley, which is fairly representative, the time of M_1 varies from about 8 a.m. at midsummer to nearly 10 a.m. at midwinter, consequently following the sunrise. On considerable mountains, however, the circumstances are exactly opposite: M_1 coming later as the sun gets nearer the zenith, so that in some cases M_1 almost or quite merges into M_2, as, for example, at Great St. Bernard, where the summer oscillation of the barometer resolves itself into a single wave, with only one maximum and one minimum in the day. Buchan has drawn a very instructive set of curves for Mount Washington, shewing the average diurnal oscillations at four different altitudes during one June. It appears from these that the time of M_1 falls about 8 a.m., at 2,900 feet, about 10 a.m. at 4,060 feet, about 11 a.m. at 5,500 feet, and about noon at 6,300 feet, whereas there is very little difference in the respective times of the other phases. Incidentally also his curves shew that m_1 gets deeper and m_2 shallower with increasing altitude. It is curious that at some places close to sea level in N.W. Europe the diurnal oscillation in summer is almost exactly like that on high peaks, namely, M_1 is retarded until it almost, or quite, merges into M_2. In the winter, however, the mountain and valley curves are much more nearly like those of the plains in the same latitude. (Fig. 4.)

According to Sir John Eliot, the amplitude of the night oscillation in India generally is least from April to July, when days are longest, the temperature and its diurnal range excessive, and the air very dry. He gives also the average times of the different phases as follows:

	Tropical India.		Extra-Tropical India.	
	h.	m.	h.	m.
m_1	3	29	3	27
M_1	9	27	9	41
m_2	16	6	16	32
M_2	22	19	22	31

I give in a Table the average monthly ranges of the barometer from one phase to the next at Kimberley, and also the difference between the mean heights of the maxima and minima, together with the amount by which m_1 falls below the mean (Table 2).

One very remarkable feature in this Table is that the difference between the mean monthly heights of M_1 and M_2 is practically constant throughout the year. The differences between the mean

monthly values of m_1 and m_2, on the other hand, are twice as great in the summer as they are in the winter. Also the mean monthly differences between any two other given phases vary considerably month by month.

The fact that there is some sort of diurnal oscillation of the barometer has probably been known for more than two centuries; but it is only within the last century that any really scientific effort has been made to understand it. In 1666 Dr. Beale, an old Cambridge man, observed that generally, in settled and fair weather, the mercury stands higher than it does during rain or storm; and often, both in winter and summer, is higher in the colder mornings and evenings than in the warmer mid-day. No great advance upon this seems to have been made for many years (excepting that the fact of the diurnal oscillation impressed itself gradually upon observers), chiefly, perhaps, because of the imperfections of barometers in those days. For it was not until 1738 that Orme invented his method of thoroughly boiling the mercury in the barometer tubes. Indeed, so little attention was paid to the phenomenon that there is not a single paper devoted to it in the *Philosophical Transactions*, at any rate, down to the beginning of the 19th century. Dalton, in the first edition of his ***Meteorological Observations and Essays*** (1793), does not so much as allude to it, though he deals at some length with barometric variations from day to day. In his second edition (1834) he mentions it, without apparently suspecting that the oscillation is semi-diurnal, and ventures upon an explanation of the cause of it. Even Harvey, in his otherwise excellent *Meteorology* (1845), wastes no words over it at all. Meanwhile Hudson (1832) had made a series of hourly observations at the rooms of the Royal Society, and determined the mean diurnal curve with a considerable degree of exactitude. It was, however, only within the last 50 years that the matter was seriously taken up, during which time a number of theories of undoubted merit have been propounded. One or two of these I propose to mention as illustrating the progress of meteorological methods.

Here is Sir John Herschel's account of the barometric oscillation as it was regarded in his day:—

> "(165.) The periodic fluctuations of the barometer are annual and diurnal. The consideration of the former will enable us to form a neater conception of the mode in which the latter arise. When it is summer in one hemisphere it is winter in the other. Hence the air generally incumbent on the heated hemisphere is dilated, and expands both upwards and laterally not only by its own increased elasticity, but also by the increased production of vapour. It therefore not only encroaches on the other hemisphere by lateral extension, but, what is far more influential, flows over upon it. In order to perceive clearly the nature of the process, we must separate in idea the aqueous and aerial constituents of the portion of the atmosphere so transferred. The generation of the former goes on in the heated hemisphere, and replaces, in part at least, the loss of pressure arising from the transfer of air, while in the other the excess

of vapour so introduced is constantly undergoing precipitation, and is thus continually being withdrawn from the total mass, leaving behind it, however, to accumulate, the dry air which accompanied it. Thus, if we regard the total barometric pressure as sub-divided into that of the dry air, and of the aqueous vapour, and denote the former by P, the latter by V, we see that the dry pressure is diminished in the hot, and increased in the cold hemisphere, without any countervailing action, while V is in process of increase from below by evaporation, and of diminution from above by overflow, in the former: and *vice versâ* in the latter. If, then, the observed barometric pressure at every point in either hemisphere be analysed by calculation into its two constituents, by taking account of the hygrometric state of the atmosphere, and subtracting from the total pressure P+V the portion V due to the amount of vapour present, the remainders ought to exhibit, as a general result, an excess of dry pressure P in the winter hemisphere over that in the summer.

"(166.) So far as observation has hitherto gone, this result is perfectly corroborated, though, unfortunately, there are not yet accumulated sufficiently numerous and extensive series of observations in which the effects of the aqueous pressure can be duly separated from the dry. As examples, we shall select the series for the Indian stations, Calcutta, Benares, Seringapatam, and Poonah, calculated by Dove from the observations of Prinsep, Sparmann, and Colonel Sykes, as compared with that at Apenrade from those of Neuber, and with the results obtained in the meteorological observatories of Prague, Toronto, and Hobart.

STATIONS.	P.—Pressure of Dry Air.			V.—Pressure of Vapour.		
	Max. in.	Min. in.	Difference.	Max. in.	Min. in.	Difference.
			Inches.			Inches.
Calcutta ...	Jan.	July	1·019	Aug.	Jan.	0·551
Benares	Dec.	July	1·244	July	Dec.	0·645
Seringapatam ...	Jan.	June	0·455	May	Jan.	0·217
Poonah	Dec.	June	0·760	July	Dec.	0·435
Apenrade ...	Feb.	July	0·450	July	Jan.	0·346
Prague	Dec.	July	0·383	July	Jan.	0·285
Toronto ...	Dec.	July	0.271	Aug.	Feb.	0·380
Hobart	July	Nov.	0·218	Feb.	July	0·125

These differences are large quantities; but we see that as the maxima of P correspond in point of time with the minima of V, it is only their differences which constitute the total or observed annual fluctuation of barometric pressure.

"(170.) The great length of time in which the efficient causes are acting in one direction, to produce the annual oscillation in question, admits of a very considerable fraction of the atmosphere to be transferred from hemisphere to hemisphere, and to allow a range in the values of P, for instance, to the large extent (as we have seen in the case of Benares), of nearly an inch and a quarter of mercury, partially neutralised by a fluctuation of more than half-an-inch of aqueous vapour. Thus the effects are brought out into prominence, in both elements, by the long-continued action of the causes; and thus, by the study in the first instance of the annual oscillation, we are led to any easy understanding of the perfectly analogous phenomena in the diurnal oscillations (or, as they have sometimes, though, in fact, improperly, been called, 'atmospheric tides'), which have a good deal perplexed meteorologists, but whose analysis into what we have for convenience called wet and dry pressure, has happily been suggested by M. Dove as affording a rational explanation.

"(171.) To simplify our conception of the diurnal oscillation, we will suppose the sun to have no declination, but to remain constantly vertical over the equator. The surface of the globe will then be divided into a day and a night hemisphere, separated by a great circle passing through the poles, coincident with the momentary horizon, and revolving with the sun from east to west in twenty-four hours. The contrast of the two hemispheres, both in respect of heat and evaporation, in this case will evidently be much greater than in that of Art. 165, and therefore the dynamical cause, the motive force, transferring both air and vapour from the one to the other, will be much greater. But, on the other hand, much less time is afforded for this power to work out its full effect, and long before this can be accomplished for any locality, the circumstances are reversed, and a contrary action commences. The causes, then, and the mode of their agency, are perfectly analogous, in the production whether of the annual or diurnal oscillation; but in the former the feebler acting cause is aided by the very much greater length of the period; in the latter its superior intensity is in great measure neutralised by the frequency of its reversal.

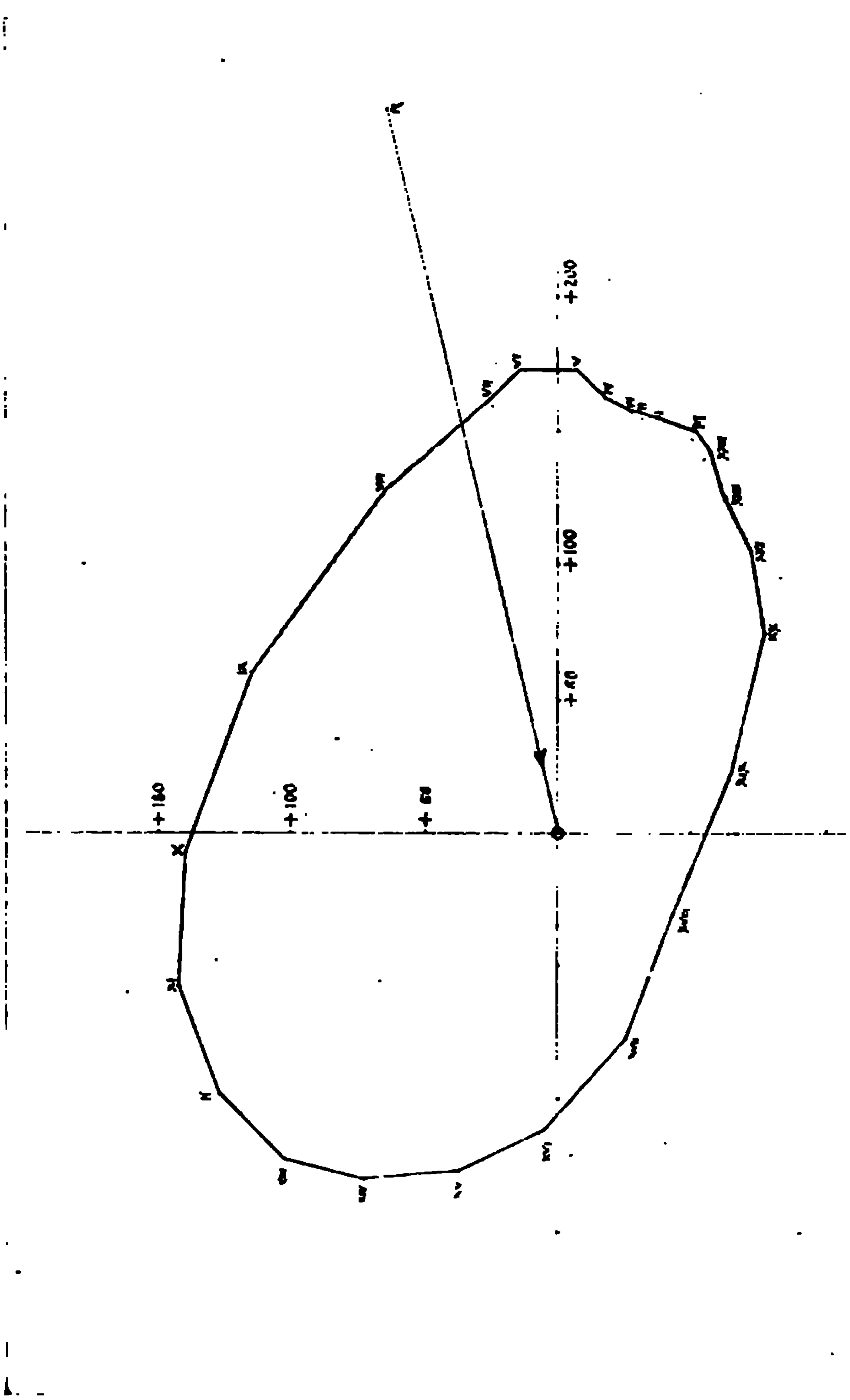
"(172.) It ought to be observed, that the oscillations in question are only in appearance analogous to those of the oceanic tides. In the latter the tide wave is merely a circulating form without any bodily transfer to any great distance. The sun's heating action is not one which, destroying a portion of its gravity, tends to alter its form of equilibrium, but one which, leaving its gravity unaltered, tends to throw its strata by their dilatation, and by the introduction of vapour from below, into forms incompatible with equilibrium, and therefore necessarily productive of lateral movements. When anemometry is further perfected, we may expect to trace the influence of this chain of

causation into a morning and evening tendency of the wind (on a long average of observation), to draw towards the time of sunrise and sunset, to compensate the overflow from off the heated hemisphere which takes place aloft in a contrary direction."

I have quoted these passages in full, because they stand for what, 40 years ago, was regarded as proved. Two assumptions—which, however, were not then thought to be assumptions—underlay the theory: one, that the air expanded by the heat of the sun flows upwards and outwards from the light hemisphere to the dark; the other, that what is called the "pressure of dry air" can be obtained by subtracting the vapour pressure, as determined by the hygrometer, from the total barometric pressure.

Now the diurnal variation of wind-direction is not quite in accordance with Sir John Herschel's idea. Taking Kimberley as an example, since we have here no very decisive prevailing wind-direction, we ought to be in a very good position to detect any drawing of the wind if it exist. But what really happens is this: Though there is no decisive prevailing direction when the whole year is considered, there is some tendency to a seasonal prevailing direction, which, in the course of the year, backs completely round the compass. Thus in the spring the prevailing direction is S.W., in the summer nearly N., and in the winter about S.E. But superimposed on this is a strong diurnal rotational veering of the vane evident at all seasons. (Fig. 5.) In this diurnal scheme the normal direction is N.E. at sunrise, N.W. at noon, S.W. at sunset, and S.E. at midnight. Now, all over the world this same diurnal rotation may be with more or less trouble separated from the prevailing directions. It has been demonstrated for several stations in India. I have shewn that it is quite obvious, even at East London, where the prevailing directions (with high velocities) are almost exclusively N.E. or S.W.—i.e., up or down the coast. (Fig. 6.) If we separate this rotational veering into its mechanical components at right-angles N. and E., we find that the E. component varies directly with the temperature of the air, and therefore indicates some such relation to the prevailing direction, as the diurnal temperature variation does to the annual. Also, if we combine velocity and direction, there is some sort of obscure agreement between the E. component wind *movement* and the barometric phases, which is chiefly noticeable in the second of the periodic terms in the sine series representing each. More than this cannot be said. Now this rotational veering of the vane implies, as F. Chambers has pointed out, not a movement inwards of the air to replace that which is supposed to have flown off above, but an outward movement, that is, not a convection current, but an anti-convection current. Also the diurnal velocity of the wind is not greatest at 4 p.m., when the barometer is lowest, as it perhaps might be if there were a partial vacuum to fill, but is greatest some hours earlier—earlier, indeed, in some months than the epochs of maximum air-temperature. It cannot be said, therefore, that the supposition

of diurnal air movements analogous to the annual ones is sufficiently substantiated by facts to explain the diurnal variations of the barometer.



COMPONENT WIND DIRECTIONS AT KIMBERLEY.
The Times are for the Hours ending—.
FIG. 5.

Coming now to the P.-V. theory, we raise the dust of ancient polemics. Is the spring of the air the same as its gravity? Is the total pressure of a mechanical mixture of gases equal to the sum

of the pressures of the separate gases? Is the pressure of the aqueous vapour in the air the same as it would be in an atmosphere of aqueous vapour independently existing? And, if all these things are provable say under the receiver of an air pump, are they necessarily true at large? To all these relatively important side issues it is not necessary to-day to volunteer a direct answer. We may confine ourselves to the simple question (1) whether it is legitimate to subtract the observed vapour tension from the barometric pressure; and (2), if so,

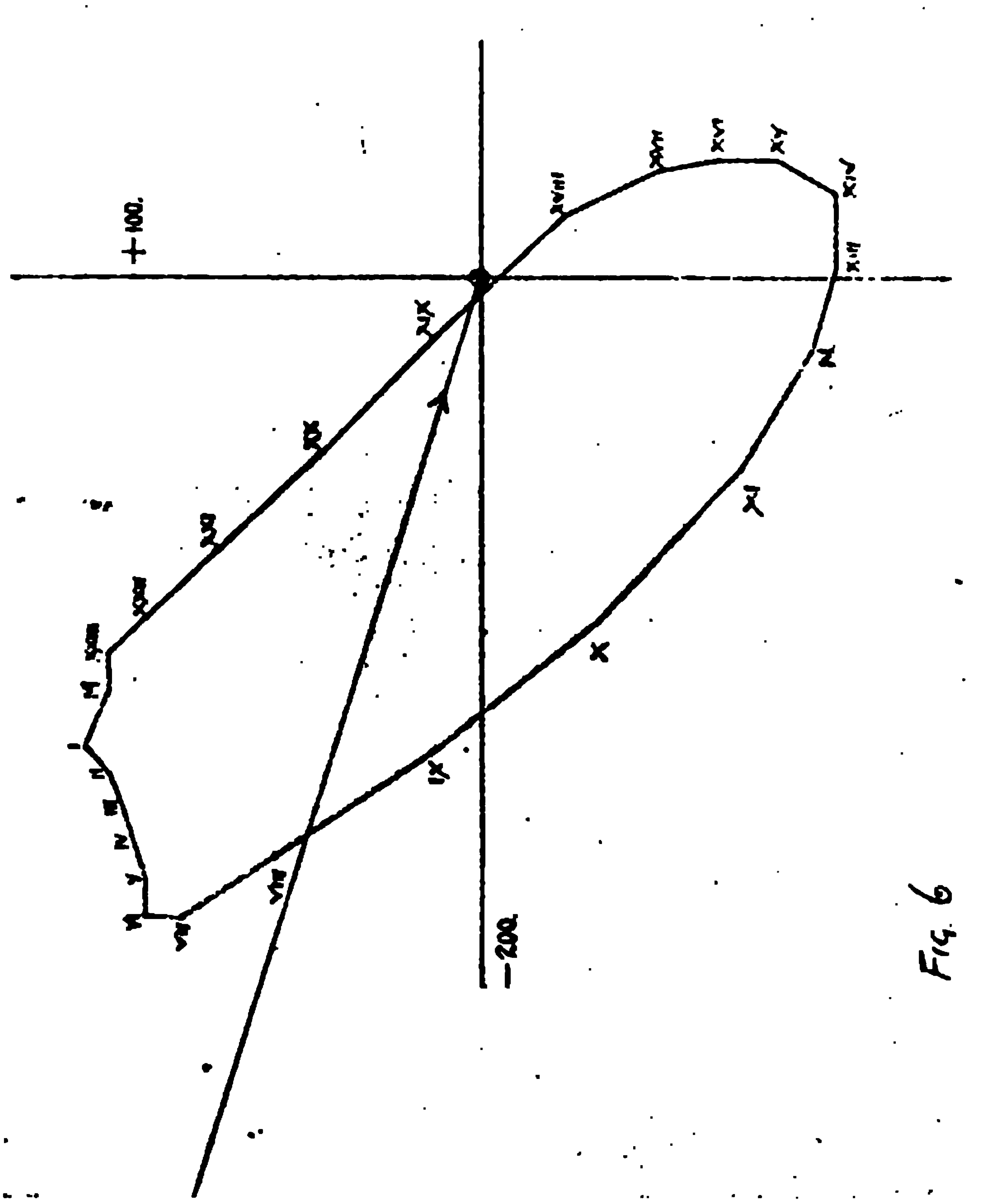


Fig. 6

COMPONENT WIND DIRECTIONS AT EAST LONDON.

whether the remaining "pressure of dry air" may be shewn to vary throughout the day in some manner depending upon the temperature? The answer to the first part of the question is that it is not legitimate. It has been shewn more than once that the pressure on the barometer of the total quantity of aqueous vapour in the air is only perhaps a quarter of what is called the vapour tension. Moreover, it varies considerably from place to place over areas throughout which the total barometric pressure may not be much affected. And even if we

take the average "pressure of dry air" over large areas, so as to eliminate local irregularities, it is still certain that the resulting diurnal variation of this pressure of dry air is not much, if any, simpler than the diurnal variation of the barometer. All this is pretty certain, and yet, to my mind, it by no means follows, as some meteorologists have, perhaps, too hastily assumed, that the semi-diurnal wave of pressure is not mainly due (indirectly though it may be) to the presence of aqueous vapour. We have to begin with the fact already mentioned that in the interior of great continental areas, where the air is necessarily dry, the night minimum becomes very small, whereas in maritime situations it is great. Again, the annual averages of vapour tension for each hour of the day at land stations give a curve with a strongly-pronounced double maximum and minimum. Also in such a place as Kimberley if we resolve both the diurnal variation of pressure, and of vapour tension, into their harmonic constituents, the epochs of the second, third, and fourth harmonic terms are almost the same in each. And it is also a curious fact that if from the total barometric pressure we subtract one-third of the observed vapour tension for each hour the resulting differences fall upon a curve which contains practically no third or fourth term. Now, it has been argued that the resemblance between the annual curves of the diurnal variation of the barometer and of the vapour tension is purely fortuitous since it is not found in the monthly curves. Such an argument does not seem to me to be quite sound. For although the diurnal curves of barometric pressure and vapour tension do differ from each other month by month, yet such variation as there is is in the same direction. For instance, if we draw winter, summer, and annual curves of the diurnal variation of barometric pressure and dew point as observed at Kimberley, we find that the winter deviations of both are positive before noon and negative after, as compared with the annual curves of each, and *vice versâ* in summer.

Now, a moment's consideration will shew that this is exactly what it should be in all places where the relative humidity is not great, if the observed variations of barometric pressure indicate any movements at all of the air. For, supposing at any instant we have in a given space a barometric pressure of 26·140 inches, and that the vapour tension is 1 % of this, i.e., ·2614 inch. Suppose further for any reason an indraught of air of the same composition, not necessarily lateral, raising the barometric pressure pretty quickly to 26·240 inches. Is it not clear that the vapour tension must have increased in the same time to ·2624 inch? Therefore I say that all variations of barometric pressure that depend solely upon air movements must give rise to similar variations in the vapour tension. But it is truly said that over the ocean, or at great altitudes, the semi-diurnal curve of vapour tension does not exist, and that the observed curve is to all appearance a temperature curve. No doubt! But, then, it must be borne in mind that in all places where the relative humidity is high movements of air are as likely as not accompanied by changes of state in its contained water vapour.

When the air is unsaturated the barometric pressure may continually increase, and the vapour tension may increase in the same ratio; but when the saturation point is reached the proportion no longer holds, and the curve of vapour tension must necessarily be controlled by the temperature of the air. At the dew point a fall of temperature means in general a deposit of dew, or some condensation of moisture, and therefore a decreased tension; a rise of temperature in the presence of water no less means evaporation. Consequently if we are looking for relationships between barometric pressure and vapour tension, over the ocean will not be the place to find it.

Dalton's explanation of the diurnal oscillation of the barometer alluded to before was partly based on suppositions respecting the behaviour of the vapour of water which, under certain circumstances, are undoubtedly realities. Since it seems not to be generally known, and also *refutes* certain opinions which a later generation has credited him with, I take this opportunity to quote it:—

> "Another *fact* respecting the variation of the barometer indeed appears to be well established, by the attentive and careful observation of that instrument. I mean the diurnal variation first observed in the torrid zone, and since then traced through the temperate zone, though it is there blended with other and more powerful variations from other causes.
>
> "Generally speaking, the fact is this: that early in the morning, about sunrise or soon after, the barometer is higher, all other circumstances the same, than it is afterwards; that it droops a little as the heat of the day advances, and is lowest nearly in the warmest part of the day; after which it rises as the air cools, and in the evening nearly recovers what it had lost since morning.
>
> "The sun's power being greatest in the torrid zone, this effect of it (for it is evidently an effect of temperature) is there a maximum; and on this account it is more conspicuous there, as well as on account of the other variations being of less magnitude than in the temperate and frigid zones. The effect diminishes, in leaving the equator, in some proportion as the latitude, the seasons, and other circumstances.
>
> "The sun is constantly heating the earth and air successively from east to west: the air being heated expands in various direction to restore an equilibrium of pressure; if this expansion was only in a perpendicular direction, it would not disturb the barometer; but as the air will go in any direction where the pressure is least, it has a lateral motion as well as a perpendicular one; and hence the column pressing on the mercury is less in quantity during the high temperature; but when the excess of temperature is withdrawn, the air falls back into its former position.
>
> "It will be perceived that the principle we have adopted in the Essay on the Variation of the Barometer is that an equality of *elasticity* in two vertical columns of air will in great part counteract an inequality in their *weight*. To illustrate this

position: suppose a cylindric vessel of indefinite length were filled with hydrogen gas, and placed perpendicular to the ground plane, having no communication with the atmosphere; suppose then that a small hole were made in the side of the said vessel at a point where the elasticities of the two gases were equal. A communication being now open an intercourse would immediately commence; but this would not be occasioned by the specifically heavy gas rushing into the light gas, nor the light gas into the heavy gas exclusively. The two gases, having equal elastic forces, would by virtue of those forces be diffused through each other slowly and gradually according to the law which I have pointed out in another Essay,—that of one gas being as a vacuum to another in regard to their mutual diffusion.

"The application of this principle in accounting for a temporary existence of a warm, vapoury volume of atmosphere supporting itself against heavier, but colder, volumes of atmosphere on the right and left of it is too obvious to be insisted upon. . . . . .

"From these observations it is not difficult to conceive that a vertical column of warm, vapoury air may be projected into a heavier column of cold, dry air, such that their *elasticities* may be nearly equal for a time, but that the adjustment of their *weights* may require a slow and gradual operation, sufficient to account for the interval of time observed between the extreme and mean state of the barometer."

Buchan made the first material advance since the time of Dove in explaining the barometric oscillations, and he followed Dalton in distinguishing between weight and elasticity, without going to the lengths of claiming that the pressure on the cistern of a barometer at any instant is that of the whole weight in the vertical column of air resting upon it. His view I also quote in full from the ninth Edition of the *Encyclopædia Britannica* :—

"If the temperature of the whole of the earth's atmosphere were raised, atmospheric pressure would be diminished, for the simple reason that the mass of the atmosphere would thereby be removed to a greater distance from the earth's centre of gravity. Quite different results, however, would follow if the temperature of only a section of the earth's atmosphere were simultaneously raised, such as the section comprised between Long. 20° and 60° W. The immediate effect would be an increase of barometric pressure, owing to expansion from the higher temperature; and a subsequent effect would be the setting in of an ascending current more or less powerful, according to the differences between the temperature of the heated section and that of the air on each side. These are essentially the conditions under which the morning maximum and afternoon minimum of atmospheric pressure take place.

"The earth makes a complete rotation round its axis in 24 hours, and in the same brief interval the double-crested and double-troughed atmospheric diurnal tide makes a complete

circuit of the globe. The whole of the diurnal phenomenon of the atmospheric tides is therefore rapidly propagated over the surface of the earth from east to west, the movement being most rapid in equatorial regions, and there the amplitude of the oscillations is greater than in higher latitudes under similar atmospheric, astronomical, and geographical conditions. Owing to the rapidity of the diurnal heating of the atmosphere by the sun through its whole height, some time elapses before the higher expansive force called into play by the increase of temperature can counteract the vertical and lateral resistance it meets from the inertia and viscosity of the air. Till this resistance is overcome, the barometer continues to rise, not because the mass of atmosphere overhead is increased, but because a higher temperature has increased the tension or pressure. When the resistance has been overcome, an ascending current of the warm air sets in, the tension begins to be reduced, and the barometer falls and continues to fall till the afternoon minimum is reached. Thus the forenoon maximum and afternoon minimum are simply a temperature effect, the amplitude of the oscillation being determined by latitude, the quantity of aqueous vapour overhead and the sun's place in the sky. . . . . .

"When the daily maximum temperature is past, and the temperature has begun to fall, the air becomes more condensed in the lower strata, and pressure consequently at great heights is lowered. Owing to this lower pressure in the upper regions of the air, the ascending current which rises from the longitudes where at the time the afternoon pressure is low flows back to eastward, thus increasing the pressure over those longitudes where the temperature is now falling. This atmospheric quasi-tidal movement occasions the P.M. increase of pressure, which reaches the maximum from 9 p.m. to midnight according to latitude and geographical position. This maximum is therefore caused by accessions to the mass of the atmosphere overhead contributed by the ascending currents from the longitudes of the afternoon low pressure immediately to the westward.

"As midnight and the early hours of morning advance, these contributions become less and less, and at length cease altogether, and pressure continues steadily to fall. But between the time when the increase of pressure from the overflow through the upper regions of the atmosphere ceases and the time when pressure increases from the heat rays, direct or indirect, of the returning sun, or during the hours of the night when the effects of nocturnal radiation are at the maximum, pressure is still further reduced from another cause. Radiation towards the cold regions of space takes place, not only from the surface of the globe, but also directly from the molecules of the air and its aqueous vapour. The effect of this simultaneous cooling of the atmosphere through its whole height is necessarily a diminution of its tension. Since this takes place at a more rapid rate than can be compensated for by any mechanical or tidal movement of the atmosphere from the

regions adjoining, owing to the inertia and viscosity of the air, pressure continues to fall to the morning minimum. This minimum is thus due, not to the removal of any of the mass of air overhead, as happens in the case of the afternoon minimum, but to a reduction of the tension or pressure of the air consequent upon a reduction in the temperature through radiation from the aerial molecules towards the cold regions of space."

This differs somewhat (and for the better, I think) from Buchan's explanation given in the *Challenger Report*, in which the morning maximum is said to depend in part upon the "vitally important principle. . . . . . that a portion of the aqueous vapour of the atmosphere passes from the gaseous to the liquid state, thus reducing the tension," and an inverse process as a contributing cause of the morning maximum.

The great virtue of Buchan's theory, to my mind, lies in his definite acceptance of the principle that a great portion of the barometric oscillation may be due to tension as distinguished from lateral movement, and rejection of the principle that the diurnal oscillation differs only in degree from the annual circulation. Indeed, the weak spot in his theory is in the hypothetical nature of these same lateral movements, and for which he adduces next to no evidence. The high velocities that would be requisite if an air particle is to move all the way from m_2 to M_2—about a thousand miles an hour at the equator—seem to have escaped attention; and also the complicated nature of the circulation necessary to restore equilibrium. For the movement in the first instance will not be a simple flow from where the atmospheric strata are most elevated to where they are most depressed; but will (or should) operate most vigorously where the gradients are steepest. That is, any outward tendency of the wind due to an elevation of the atmospheric strata should display its most marked effect near the times of sunrise and sunset, when temperatures are changing most rapidly, and should be directed to some point not the shortest path down the slope. As we have seen, this is pretty much what happens at Kimberley, and, as I have shewn elsewhere, our normal wind directions at any hour are tangents to an imaginary spiral curling outwards from the light hemisphere and into the dark. Another point which seems to want demonstration, or, at any rate, elucidation, is the local character he endeavours to give to his theory, namely, that the barometric oscillations are generated by absorption and radiation in the regions where they occur. It is difficult to believe that physical processes which can only generate a total range of temperature over the ocean of one or two degrees can give rise to a range of pressure often greater than it is in continental places, where the range of temperature is twenty times as great. Moreover, it has yet to be shewn that the absolute humidity (upon which absorption depends), and the relative humidity (upon which radiation mainly depends), are materially less at great altitudes over the land than they are over the ocean. Over Kimberley, at any rate, the upper air must be nearly or quite as rich in aqueous vapour as the upper air is over the eastern Atlantic. For our upper currents seem to set almost constantly from

the West. Nearly all our clouds come from some westerly direction, and since they pass over one of the driest areas in the world, depositing very little moisture on the way, it follows that they must be nearly or quite as rich in moisture as when they left the high levels over the Atlantic. Therefore such difference as there is between the absorption and radiation over land and sea must be more pronounced in the lower levels than in the upper.

Regarding the curious diurnal variations of pressure characteristic of valleys and mountains, it has long been recognised that it is a thermal result quite independent of the primary causes of the general barometric oscillations over the earth's surface.

Recently Prof. Bigelow has attempted a comprehensive theory of the diurnal oscillations of all the chief meteorological elements. Here again I quote at some length :—

> " Let us illustrate the formation of the double diurnal period at the earth's surface and the single period in the cumulus level by considering the behaviour of the absolute humidity, that is, the number of grams of water vapor per cubic centimeter. The first diurnal effect of the radiation from the earth is to raise the vapor content of the atmosphere from the low level occupied by it at night to a higher level during mid-day. This absorbing screen of water vapor, visible or not, rises and falls once daily through 1000 or 2000 meters, taken as a whole. While the warm air rises by convection from the surface to the level of 1500 meters, the vapor rises with it and endeavours to saturate the unit volumes of the higher strata at the prevailing lower temperatures, the depleted lower volumes being *partially filled up again by fresh evaporation* from the water and land surfaces. . . . . . There is a decrease in actual temperature with the elevation, and therefore the saturated unit-volume content decreases. The vapor sheet rises to higher levels, and this, together with the fresh supply by evaporation from the surface, can refill the depleted volume again, especially during the forenoon hours. After the noon hour the continued increase of temperature gives rise to larger vapor capacity per unit-volume. . . . . . But while the rising vapor sheet keeps the upper volumes filled, the lower, which are drained by the ascension of the water vapor, can not be supplied by evaporation at the surface at a sufficiently rapid rate to keep them full, because the prevailing surface moisture has been taken up at an earlier hour. The same remarks are true for the relative humidities. The result is that the upper volumes are always full or relatively full, and have an increasing actual content up to the early afternoon, about 2 p.m., so that the diurnal curve at some distance above the ground has a single maximum and minimum as observed. On the other hand, while the 10 a.m. surface volumes are kept filled, or relatively filled, they are actually depleted in the afternoon, and are not replenished by evaporation up to the original relative humidity of the morning, and therefore the curve shows a depression in the early afternoon, and is doubly periodic. The second maximum

at the surface is due to a reversal of this process as the vapor settles back slowly to the ground during the afternoon and night. The additional lag of the evening maximum being four hours in the evening to about 10 p.m. is due to the slow cooling of the ground after sunset, which continues to be a source of heat for several hours, and the slow conductivity of the heated atmosphere, which retains its heat even longer than the ground after the sun has set. This theory, if pursued into quantitative details, will evidently account for the entire series of observed phenomena. . . . Analysing the diurnal barometric pressure by volume contents, we see that with the heating of the lower strata the denser air of night is replaced by contents of lower density after mid-day; taking into account the lag, the lower volumes are depleted and the upper are filled relatively, thus producing the two types of periods. This is entirely analogous to the barometric pressures of winter and summer, wherein the summer pressures are lower [than those of winter] at the surface of the earth, but greater at some such level as 1500 or 2000 meters, the summer pressure corresponding to that of the diurnal pressure in the afternoon. . . . . . . It is inferred from these considerations that since the double diurnal period is confined to a thin sheet near the surface and does not extend throughout the atmosphere, Lord Kelvin's theory of a dynamic forced wave is not available for explaining this phenomenon."

There seem to me—I hope you will agree that I am speaking with all diffidence as one seeking rather than imparting information—there seem to me great difficulties in Prof. Bigelow's exposition. In the absence of direct proof it is surely difficult to believe that there can be such an enormous vertical circulation of air extending from the bottom to an altitude of upwards of 10,000 feet as seems to be implied. Then there is the circumstance that over the ocean the vapour tension varies with the temperature and has only a single maximum and minimum in the day, whereas the pressure of the air has a semi-diurnal period as strongly pronounced as it is over the land, in spite of the almost uniform temperature of the lower air and of the floor upon which it rests.

Now, I have troubled you at so much length with these various theories because each one seems to me to contain something worth attention. Certainly they all display a certain amount of irresponsible slurring over difficulties, and base their strongest pretensions on what we know least about; nevertheless they are not to be entirely rejected on that account. They compare very favourably, at any rate, with some of the theories that have attained transient currency in other sciences.

The most important contribution so far made to the theory of the diurnal oscillation of barometric pressure is due to Hann. This renowned meteorologist has done a vast amount of work in classifying and generalising the harmonic elements of the pressure variations for a great number of stations, and has succeeded in establishing a number of results of the first importance. Harmonic

analysis, as it is called, is of considerable importance in many branches of physics. It is based on the principle that the summation of any number of harmonic curves is a periodic curve. The task of the meteorologist is the laborious inverse process: the separation of the various periodic curves met with in meteorology into their harmonic constituents as far as possible. Most of the diurnal meteorological curves well repay analysis as far as the fourth harmonic, the curve of diurnal barometric variation in particular. The periodic formula as it is usually employed in meteorology is, for hourly observations,—

$$\begin{aligned} a = p &+ u_1 \sin (V_1 + n\ 15^\circ) \\ &+ u_2 \sin (V_2 + 2n\ 15^\circ) \\ &+ u_3 \sin (V_3 + 3n\ 15^\circ) \\ &+ \ldots\ldots\ldots\ldots \end{aligned}$$

where p is the mean value,
u_1, u_2, u_3,............the amplitudes, and
V_1, V_2, V_3,............the epochs

of the first, second, and third harmonic terms respectively.

Now, Hann has established that in the case of the barometric pressure, up to latitude 48° at least, u_2 is greater than u_1, and, indeed, considerably the greater over the tropical oceans. Also that the flood-time of the semi-diurnal barometric wave is very constant over pretty well the entire globe. The flood-time of the diurnal wave, however, varies widely according to the latitude and topography of the station.

Table 3 gives the various harmonic elements for the four barometer curves of Fig. 1, together with one or two others for comparison. I have also added harmonic elements of vapour tension for Kimberley, Lisbon, Córdoba, and Hong Kong. You will see from these that the epoch of the semi-diurnal wave of pressure comes later on the whole (i.e., the constant angle gets smaller) as the latitude increases, saving in the case of the station near the Arctic Circle.

Let me now quote a passage or two from a comparatively recent paper by Hann as expressing some of his latest views:—

> "I was myself convinced that all the attempts to explain the diurnal barometric oscillation by means of the daily variations of the meteorological elements at any one place. . . . could lead to no conclusion; and I have published a series of papers giving a precise description of the phenomenon as manifested over the whole earth, at sea-level as well as at all elevations for which observations exist, and I have endeavoured to give the results in such a form as would be suited for the basis of a physico-mathematical theory. With this object I have represented all the results of observations in periodic functions.
>
> "I am of opinion that, speaking generally, the observed daily variation of wind and temperature do not stand in as close a relation to the diurnal barometric oscillation as has hitherto been assumed. . . . . . We had better deal with the action of the sun on the upper strata of the atmosphere, and treat this as the principal cause. The actinometrical observations show us that

these upper strata absorb a considerable amount of heat. This diurnal heating action of the sun on the upper strata would harmonise far better with the general uniformity of the daily barometric oscillation along the different parallels of latitude, as well as with its general independence of weather. We need not quite exclude local influences, but these seem to be more of a secondary character.

"Inasmuch as the *periodical* action of the sun's rays on the *upper strata* of the atmosphere, recurring day by day, must produce periodical movements of great regularity (an oscillation of the entire mass of the atmosphere), it is easy to see that this can explain the typical character of the diurnal barometric oscillation, while the local differences of the earth's surface represent the modifying element.

"If a limited mass of fluid is set in simple pendulum-like oscillations, their amplitudes are governed by the given conditions of the fluid or the gas (dimensions, temperature). If the impulse is a single powerful one, such as that which gives rise to seiches in lakes, it is perfectly immaterial how it goes on: the mass of water takes up always the same pendulum movement in which it can move in virtue of its dimensions (the length and depth of its basin).

"If the impulse recurs periodically, then oscillations of that period are *forced* to occur, even if these do not coincide with any any of the forms of oscillation which belong to free waves. This holds if the impulse represents a simple sine wave. In other cases the following must be considered. Fourier showed mathematically that any periodical form of oscillation (or wave of any form) can always be resolved into a sum of simple pendulum oscillations (waves), and that their number of oscillations are 1, 2, 3, times as great as the number of oscillations of the given form of movement, and only in one *single* manner. When any periodically recurring impulse of any form is resolved by Fourier's harmonic analysis into pendulum oscillations, each portion of these produces a forced oscillation of the same period in the mass of fluid. But the amplitudes of these forced waves do not preserve the same proportion to each other as those of the waves which produce them. If the period of an exciting wave is nearly the same as that of a free wave in the liquid, the resulting forced oscillation will attain a disproportionally great amplitude.

"This principle may be applied to the constant oscillations of our atmosphere which are produced by a periodical impulse, i.e., by the variation of temperature which recurs uniformly day by day. If the atmospherical envelope of our earth, with its conditions of space and of temperature, is most easily set in oscillations of a semi-diurnal period, the semi-diurnal portion of its exciting cause, the diurnal temperature wave, will be the most active. It does not matter whether this semi-diurnal temperature wave has a real independent existence."

That is to say, if I interpret this quotation aright, the semi-diurnal oscillation of the barometer is to be regarded as mainly a forced wave of pressure of 12 hours period due to the harmonic component wave of temperature of the same period. There have been many adverse criticisms of this view. Hann himself notices one to the effect that,—

> "There is, in reality, no daily variation of temperature with two maxima and minima; and if we, in spite of this, obtain a double daily temperature wave, because we insist on representing the daily march of temperature by a series of sines, this forced methematical form can never serve to explain an observed phenomenon, whereas for this some real natural process must be sought for as a cause."

Such an objection would only be valid if the diurnal variation of temperature were a simple impulse of 24 hours' period. In reality it is anything but that. It is itself the result of a train of acting and reacting processes, due largely to the presence of great water areas over the earth's surface, and to the presence of aqueous vapour in the atmosphere. Before the final result of a temperature impulse upon the air can be considered, we have to take into account the fact that the temperature impulse itself is largely modified by the train of operations set agoing by itself. Thus, for example, the diurnal variation of temperature gives rise to a diurnal variation of aqueous vapour. This aqueous vapour absorbs and radiates heat, thus disturbing the otherwise simple curve of temperature. Then, again, clouds are formed, and these shew a tendency to two, or, perhaps, three maxima in the day. These also regulate the temperature. Then, as Hann has observed, insolation by day and radiation by night combine to made the diurnal curve of temperature asymmetrical, and composed of two parts which do not follow the same law of variation. For all these reasons it seems clear that the various harmonics are not necessarily figments of the mathematical imagination. The strongest objection, to my mind, against the second harmonic wave of temperature being the ultimate cause of the semi-diurnal oscillation of pressure, is that for all altitudes known to us the variation of the one month by month differs considerably from that of the other. Taking Kimberley as an example, we find that the maximum phase of the second harmonic wave of pressure comes earliest in October and latest in February, the difference in time being almost exactly one hour; whereas the same epoch in the second harmonic wave of temperature is earliest in October and latest in July, the difference in time being more than two hours. And nearly the same rule holds up to altitudes of 15,000 feet, if not more. A second objection takes the form of a query: Have we exhausted every other possible source having an indubitable 12-hour period? There is, for example, the evaporation of water from the surface of the earth, which, as I have tried to explain before to-day, and as you will also see from the harmonic constants of vapour tension given above, shews strong barometric affinities. Is the semi-diurnal curve of vapour tension over the land due, as Bigelow says, to the displacement of the lower damp air by

dry air from above during the middle of the day? Is the semi-diurnal curve of vapour tension at sea, near land, due, as Buchan says, to an inter-mixture with the air forming the sea-breeze of descending thin and drier air filaments from higher levels? These points are noted here not with the idea of formulating a theory, but rather for the purpose of strengthening a criticism. Let me illustrate by citing a representative experiment from a series which I hope to discuss at length at some future time :—

Time.	Air Temp.	Water Temp.	Evaporation.	
			Interval.	Grains.
11 a.	79°	66	8 a. — 11 a.	2
2 p.	85	75	11 a. — 2 p.	8
5 p.	83	79	2 p. — 5 p.	14
8 p.	72	73	5 p. — 8 p.	22
11 p.	69	71	8 p. — 11 p.	9
8 a.	66	61	11 p. — 8 a.	17

There is nothing exceptional about these quantities of evaporation; they are quite typical of the series. The experiments were taken in a particular way for a particular purpose, and they shew that there are easy circumstances under which evaporation is not controlled by either the humidity of the air alone, the temperature of the water alone, or the rate of change of vapour tension between one level and another in the space above the water. For the rate of evaporation here shewn is greatest after sunset when on the whole the dew point is at its maximum, the relative humidity is rising to its maximum, and the temperature is falling; and, moreover, the average rate of evaporation for the three hours, 8 p.m.—11 p.m., is actually greater (often it is much greater) than during the three hours 11 a.m.—2 p.m. Now, we know that evaporation proceeds most rapidly over the land areas during the heat of the day : my experiments suggest that it is not at all impossible that evaporation over the oceans may actually be greater at night. That is to say, during a great portion of the day there may be two meridians on the earth's surface somewhere about half a rotation apart at which evaporation is going on more rapidly than it is at intervening parts : in other words, a kind of semi-diurnal oscillation of the rate of evaporation shewing its greatest effect when the sun is on the meridian of some continental area. I do not by any means assert that such a process as this, if it exist, is going to settle the question of the diurnal variation of barometric pressure; but I do assert that until we know more of the physical processes involved in the behaviour of water vapour we shall not be in a position to solve the fundamental problem.

Before closing, there is one point not without interest: The periodic formulæ for temperature are always computed for the diurnal variation—as if we expect that the barometric pressure should rise and fall as the atmospheric planes of equal pressure rise and fall (or fall and rise). Such a process, though quite orthodox, seems to me to be not necessarily the best. For there is no evidence that the annual phenomenon of simultaneous high pressure and low temperature, and *vice versâ*, has its counterpart in the diurnal process. If tension rather than weight should be in question, perhaps harmonic formulæ for the diurnal *variability*, rather than for the diurnal *variation* of temperature, are likely to lead more quickly to a result. At any rate, I have been employed lately, in spare intervals, in computing the monthly constants for a number of places whose hourly temperatures are known to me. Whatever view one may take of the method the results are certainly striking. The following are some annual values :—

	V_1	V_2	V_3	u_1	u_2	u_3
1. TREVANDRUM.						
Barometric Pressure...	24°	164°	11°	·0173	·0439	·0012
Temp. Variability ...	333	172	115	1·3280	·7000	·2890
Temp. Variation ...	240	81	21	5·3310	1·4000	·3690
2. KIMBERLEY.						
Barometric Pressure...	355°	154°	358°	·0276	·0243	·0017
Temp. Variability ...	320	150	114	3·2690	1·5680	·6540
Temp. Variation ...	229	58	16	12·0090	3·0740	·6970
3. GREENWICH.						
Barometric Pressure...	23°	144°	9°	·0028	·0100	·0011
Temp. Variability ...	327	148	129	1·3390	·5240	·1060
Temp. Variation ...	214	15	41	5·1030	1·0810	·4230

With regard to these comparative values it may be said at once that although the constant angles and co-efficients in the barometric formulæ shew a much better agreement with the formulæ for temperature variability than they do with those for temperature variation during the course of the year, the epoch of the second harmonic term of temperature variability changes from one side to the other of the epoch of the second harmonic term of barometric pressure, being earlier in summer and later in winter by half an hour or so. I am annexing some Tables, which you will have an opportunity of examining in full. One point is especially worthy of notice, namely, the constancy of the epoch of the first term of temperature variability not only throughout the year at each station, but all over the world. Thus, e.g., the epoch of the first term of temperature variation at Greenwich averages nearly two hours later than it does at Trevandrum, whereas the epochs of temperature variability are less than a quarter of an hour apart. The immutability of the epoch month by month at any station is specially remarkable if it be remembered that the time of sunrise is nearly two hours earlier in summer than it is in winter at Kimberley, and 4½ hours earlier at Greenwich. Remembering the importance of the second harmonic

wave of pressure, another fact worth attention is the relative magnitude of the amplitude of the second harmonic term of temperature variability. Relatively to the first harmonic term it is twice as important as the corresponding term in the formula for temperature variation.

[NOTE.—Since this address was delivered Mr. Innes has called my attention to a remarkable paper by Dr. Halm, published in the Journal of the Scottish Meteorological Society, Third Series, No. xxii., 1906. Dr. Halm traces the diurnal variation of the barometer, not to the temperature variability, but to the "change of the change" of diurnal temperature, i.e., to $d^2\theta/dt^2$, where θ is the absolute temperature at the time t. I should have been glad to have included a sketch of Halm's results had I known of them before. At the same time it seems to me that the temperature variability is more important than its rate of change.]

NOTES ON THE TABLES.

DARESSALAM.—I have taken the monthly means of Barometric Pressure from *Deutsche Uebersecische Met. Beobachtungen*, H. XIII., 1905, and computed from them the annual means and periodic constants for the two years 1901-2. The barometric observations made before 1901 seem to be seriously in error.

KIMBERLEY.—My own observations. Monthly means of the hourly values of Barometric Pressure are given in Table 4; the diurnal variation of Air Temperature and Relative Humidity in Tables 5 and 6; harmonic constants of Barometric Pressure, Temperature Variability and Humidity in Tables 9 and 10.

GREENWICH.—The Barometric Pressures are taken from the *Greenwich Observations*, 1883-1894. Monthly means are given in Table 4A. The harmonic constants for the individual months are copied from *Harmonic Analysis of Hourly Observations, Etc., at British Observatories*, p. 20, 1891; but the constants for the year were computed by me from the annual values of Table 1 here. A long series of observations seems required to give good monthly values of the harmonic constants at Greenwich. The harmonic constants of Temperature Variability are given in Table 8. They were computed from the hourly differences deduced from the hourly values of Air Temperature given in *Harmonic Analysis, Etc.*, p. 10. The Noon values of Air Temperature at Greenwich seem to be too great throughout the summer.

ANANITO.—The hourly values of Barometric Pressure are taken from *Met. and Phy. Observations on the East Coast of British America*, 1883.

CÓRDOBA.—The hourly values of Barometric Pressure for the year are taken from Davis, *Climate of the Argentine Republic*, p. 51, 1902. The June and December values are from the *Challenger Report*.

GREAT ST. BERNARD, KLAGENFURT, VALENTIA.—The hourly values of barometric pressure are taken from the *Challenger Report*.

AGUSTIA.—The hourly values of Barometric Pressure in Table 1 are taken from the *Indian Met. Memoirs*, X., Part 2. They are really for 30 minutes past the hour to which they stand opposite. Thus 24.067 is the pressure at 1.30 a.m., 24.057 is the pressure at 2.30 a.m., etc.

TREVANDRUM.—The harmonic constants of Barometric Pressure for this place are taken from Eliot, *Indian Met. Memoirs*, X., Part 1. The harmonic constants of Temperature Variability are computed from the hourly values of temperature given in the same Part.

In Table 3 all the harmonic constants have been computed by me, with the exception of those of Barometric Pressure for Ananito, Calcutta, and Trevandrum, and those of Vapour Tension for Córdoba. My Lisbon result agrees (after changing some signs and putting inches for mm.) with those given in *Annæs do Obs. do Infante D. Luiz*, 1888. The time is counted from local midnight in each case.

TABLE 1.—The Hourly Variation of Barometric Pressure.

	DARESSALEM. Annual.	KIMBERLEY. Annual.	GREENWICH. Annual.	ANANITO. Winter.	GREAT ST. BERNARD. Annual.	GREAT ST. BERNARD. June.	GREAT ST. BERNARD. Decem.	CÓRDOBA. Annual.	CÓRDOBA. June.	CÓRDOBA. Decem.	KLAGENFURT. Annual.	KLAGENFURT. June.	KLAGENFURT. Decem.	AGUSTIA. Annual.	VALENTIA. June.	VALENTIA. Decem.
Lat.	6° 49′ S.	28° 43′ S.	51° 29′ N.	66° 20′ N.	45° 42′ N.			31° 25′ S.			46° 37′ N.			8° 37′ N.	51° 55′ N.	
Alt.	44 ft.	3950	159	0	8130			1434			1437			6200	23	
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
M.	29·986	26·141	29·794	29·778	22·212	22·328	22·069	28·504	28·605	28·404	28·474	28·457	28·470	24·082	29·940	29·859
I.	·974	·137	·790	·773	·203	·318	·064	·496	·598	·412	·475	·457	·469	·067	·935	·853
II.	·966	·133	·786	·769	·195	·309	·057	·488	·597	·411	·474	·458	·467	·057	·927	·849
III.	·963	·130	·782	·766	·191	·305	·055	·480	·596	·408	·474	·458	·467	·052	·920	·848
IV.	·966	·132	·779	·767	.187	·302	·054	·480	·594	·408	·474	·460	·466	·057	·914	·843
V.	·974	·139	·779	·770	·188	·302	·055	·484	·592	·412	·475	·464	·465	·067	·915	·838
VI.	·989	·151	·792	·775	·191	·304	·057	·496	·592	·418	·478	·465	·467	·079	·918	·837
VII.	30·010	·163	·787	·779	·195	·307	·061	·508	·592	·426	·481	·467	·471	·098	·922	·839
VIII.	·025	·173	·793	·779	·200	·310	·066	·516	·594	·431	·482	·465	·473	·113	·927	·844
IX.	·033	·176	·796	·775	·203	·312	·073	·520	·598	·430	·480	·460	·473	·120	·931	·850
X.	·031	·174	·798	·770	·206	·313	·079	·516	·601	·424	·476	·453	·474	·118	·935	·857
XI.	·019	·163	·796	·764	·205	·314	·074	·504	·590	·414	·467	·444	·467	·107	·939	·859
N.	29·999	·143	·791	·761	·204	·315	·066	·488	·573	·404	·457	·434	·457	·091	·941	·854
XIII.	·978	·122	·785	·761	·202	·316	·060	·465	·556	·389	·445	·423	·445	·074	·941	·846
XIV.	·953	·102	·779	·764	·199	·315	·056	·449	·541	·371	·434	·413	·439	·060	·940	·840
XV.	·939	·092	·776	·769	·199	·315	·057	·433	·536	·344	·429	·407	·437	·053	·940	·838
XVI.	·933	·087	·774	·773	·200	·315	·060	·429	·537	·326	·426	·404	·440	·054	·938	·844
XVII.	·939	·089	·775	·777	·202	·315	·060	·441	·545	·321	·428	·405	·444	·062	·937	·851
XVIII.	·949	·098	·779	·779	·204	·316	·061	·449	·552	·321	·434	·410	·450	·075	·938	·855
XIX.	·959	·110	·784	·781	·208	·319	·066	·461	·562	·325	·443	·418	·456	·090	·939	857
XX.	·971	·125	·789	·782	·212	·322	·070	·480	·573	·336	·454	·430	·462	·103	·941	·860
XXI.	·988	·134	·793	·783	·214	·326	·072	·496	·582	·356	·465	·446	·468	·110	·943	·862
XXII,	·996	·141	·795	·784	·216	·329	·073	·504	·593	·376	·469	·452	·469	·107	·948	·863
XXIII.	·994	·142	·795	·782	·214	·330	·072	·508	·602	·395	·471	·455	·470	·098	·945	·861
Mean.	29·981	26·133	29·786	29·773	22·202	22·315	22·064	28·480	28·579	28·386	28·461	28·442	28·461	26·083	29·934	29·850
$M_1 - m_2$	·100	·092	·024	·018	·007	·001	·022	·091	·064	·110	·056	·063	·037	·067	·004	·021

TABLE 2.—Mean Monthly Ranges of Barometric Pressure at Kimberley (Kenilworth).

Month.	M_2 to m_1	m_1 to M_1	M_1 to m_2	m_2 to M_2	M_1— M_2	m_1— m_2	m_1 below mean
	inch.	inch.	inch.	inch.	inch.	inch.	inch.
Jan. ...	·015	·048	·097	·064	·033	·049	·005
Feb. ...	·011	·046	·099	·064	·035	·053	·001
Mar. ...	·015	·047	·086	·054	·032	·039	·005
April ...	·017	·048	·078	·047	·031	·030	·008
May ...	·014	·046	·077	·045	·032	·031	·006
June ...	·012	·048	·075	·039	·036	·027	·006
July ...	·010	·047	·083	·046	·037	·036	·003
Aug. ..	·014	·049	·089	·054	·035	·040	·004
Sept. ..	·017	·055	·103	·065	·038	·048	·005
Oct. ...	·014	·052	·101	·063	·038	·049	·003
Nov. ...	·013	·049	·107	·071	·036	·058	·000
Dec. ...	·012	·047	·105	·070	·035	·058	·000
Average ...	·014	·048	·092	·057	·035	·043	·004

TABLE 3.—Some Harmonic Constants in the Diurnal Curves of Barometric Pressure and Vapour Tension.

	V_1	V_2	V	V_4	u_1	u_2	u_3	u_4
BAROMETRIC PRESSURE.								
Daressalam	342°	158°	52°	168°	·0242	·0319	·0015	·0012
Trevandrum	24	164	11	210	·0173	·0439	·0012	·0010
Calcutta	341	151	346	254	·0265	·0391	·0012	·0013
Kimberley	355	154	358	351	·0276	·0243	·0017	·0001
Córdoba	17	150	21	291	·0275	·0279	·0007	·0004
Greenwich	23	144	9	131	·0028	·0100	·0011	·0002
Ananito	115	205	93	...	·0063	·0069	·0034	...
VAPOUR TENSION.								
Kimberley	250	154	359	328	·0135	·0060	·0050	·0006
Córdoba	216	142	318	305	·0114	·0083	·0016	·0024
Hong-Kong	130	131	144	333	·0144	·0025	·0014	·0012
Lisbon...	60	198	29	98	·0048	·0033	·0016	·0004

Table 4.—The Diurnal Variation of Barometric Pressure at Kimberley (Kenilworth).*

Hour.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
M'nt.	26·024	26·078	26·086	26·160	26·215	26·281	26·251	26·225	26·187	26·097	26·048	26·039	26·141
I.	·019	·074	·084	·157	·213	·279	·250	·221	·182	·091	·043	·034	·137
II.	·012	·071	·079	·153	·209	·278	·245	·217	·175	·084	·040	·031	·133
III.	·011	·068	·074	·147	·205	·276	·243	·214	·170	·083	·040	·031	·130
IV.	·017	·071	·075	·145	·203	·274	·241	·213	·173	·088	·046	·038	·132
V.	·028	·078	·081	·151	·206	·277	·244	·218	·182	·099	·059	·049	·139
VI.	·043	·092	·093	·160	·215	·285	·252	·229	·196	·115	·074	·064	·151
VII.	·055	·105	·105	·172	·225	·296	·263	·240	·210	·127	·085	·075	·163
VIII.	·059	·113	·117	·188	·240	·309	·275	·254	·222	·134	·089	·078	·173
IX.	·056	·114	·121	·193	·248	·319	·284	·261	·225	·135	·087	·075	·176
X.	·053	·109	·120	·192	·249	·322	·288	·262	·219	·127	·080	·068	·174
XI.	·044	·099	·110	·183	·239	·312	·277	·251	·204	·110	·065	·057	·163
Noon.	·028	·082	·093	·165	·219	·293	·257	·229	·179	·090	·046	·040	·143
XIII.	·011	·064	·074	·141	·196	·271	·232	·202	·156	·070	·026	·021	·122
XIV.	25·991	·043	·053	·124	·179	·253	·214	·182	·135	·048	·004	·001	·102
XV.	·976	·027	·041	·117	·172	·247	·207	·173	·125	·036	25·991	25·988	·092
XVI.	·963	·018	·035	·115	·172	·247	·205	·173	·122	·034	·982	·974	·087
XVII.	·962	·015	·036	·116	·177	·251	·209	·177	·127	·037	·983	·973	·089
XVIII.	·972	·023	·042	·124	·186	·260	·217	·186	·137	·047	·994	·984	·098
XIX.	·987	·037	·053	·135	·198	·268	·227	·199	·151	·062	26·009	·998	·110
XX.	26·000	·054	·071	·150	·207	·276	·236	·212	·169	·081	·028	26·015	·125
XXI.	·014	·066	·081	·157	·213	·281	·242	·220	·179	·090	·041	·030	·134
XXII.	·024	·075	·086	·162	·216	·285	·247	·226	·182	·095	·051	·041	·141
XXIII.	·026	·079	·089	·162	·217	·286	·248	·227	·183	·096	·053	·043	·142
Day.	26·016	26·069	26·079	26·153	26·209	26·280	26·244	26·217	26·175	26·086	26·040	26·031	26·133
Mean Hourly Dew Point.	° 52·4	° 52·9	° 52·9	° 47·9	° 38·7	° 33·8	° 33·0	° 33·0	° 37·0	° 41·2	° 42·2	° 46·8	° 42·9

*Eight years of observation, 1897—1904.

TABLE 4A.—The Diurnal Variation of Barometric Pressure at Greenwich. *

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
M'nt.	29·810	29·841	29·781	29·752	29·767	29·849	29·777	29·790	29·835	29·728	29·770	29·827	29·794
I.	·804	·838	·778	·746	·763	·845	·773	·785	·831	·724	·764	·823	·790
II.	·803	·836	·773	·741	·758	·841	·768	·782	·826	·718	·762	·823	·786
III.	·801	·831	·765	·736	·755	·838	·764	·778	·822	·712	·757	·820	·782
IV.	·797	·828	·762	·733	·753	·838	·764	·774	·818	·710	·752	·815	·779
V.	·794	·830	·762	·733	·756	·842	·766	·776	·818	·710	·753	·812	·779
VI.	·794	·831	·764	·739	·761	·846	·770	·781	·824	·712	·754	·813	·782
VII.	·799	·836	·770	·744	·765	·850	·775	·785	·830	·721	·758	·817	·787
VIII.	·806	·844	·776	·747	·767	·853	·777	·789	·835	·730	·765	·824	·793
IX.	·813	·848	·781	·748	·766	·853	·777	·791	·839	·730	·769	·830	·796
X.	·818	·852	·783	·748	·766	·853	·777	·791	·839	·737	·772	·837	·798
XI.	·817	·855	·782	·746	·763	·851	·775	·789	·836	·737	·770	·832	·796
Noon.	·806	·850	·779	·741	·760	·847	·772	·786	·832	·731	·763	·824	·791
XIII.	·795	·842	·770	·736	·756	·842	·769	·782	·827	·724	·756	·815	·785
XIV.	·788	·835	·762	·730	·752	·838	·765	·778	·821	·719	·750	·810	·779
XV.	·788	·832	·756	·723	·747	·833	·761	·773	·816	·716	·750	·811	·776
XVI.	·789	·832	·752	·720	·744	·829	·758	·770	·805	·716	·754	·814	·774
XVII.	·791	·836	·754	·721	·742	·826	·755	·767	·814	·721	·758	·817	·775
XVIII.	·793	·843	·761	·725	·745	·828	·755	·767	·818	·729	·765	·821	·779
XIX.	·795	·847	·768	·733	·750	·832	·758	·773	·825	·732	·769	·826	·784
XX.	·796	·850	·772	·742	·759	·838	·764	·782	·832	·734	·771	·829	·789
XXI.	·795	·853	·774	·748	·768	·848	·773	·787	·834	·737	·774	·831	·793
XXII.	·794	·855	·776	·749	·771	·851	·776	·789	·835	·737	·773	·831	·795
XXIII.	·792	·856	·777	·750	·772	·853	·777	·790	·834	·735	·773	·833	·795
Day.	29·800	29·845	29·770	29·739	29·759	29·843	29·769	29·781	29·827	29·725	29·763	29·822	29·786

* Twelve years of observation, 1883—1894.

TABLE 5.– The Diurnal Variation of Air Temperature at Kimberley (Kenilworth).*

Hour.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
M'nt.	67·7	67·3	62·9	56·2	48·2	42·5	42·1	46·7	53·1	57·9	62·2	66·7	56·1
I.	66·5	66·2	61·9	55·2	47·1	41·4	41·0	45·6	51·7	56·5	60·8	65·4	54·9
II.	65·4	64·9	60·9	54·2	46·1	40·4	40·0	44·4	50·4	55·0	59·1	64·3	53·8
III.	64·5	64·3	60·4	53·4	45·3	39·5	39·3	43·4	49·5	54·1	58·1	63·3	52·9
IV.	63·6	63·6	59·8	52·7	44·5	38·7	38·6	42·6	48·7	53·2	56·9	62·3	52·1
V.	62·8	62·9	58·9	52·0	43·7	38·0	37·9	41·8	47·7	52·2	55·9	61·5	51·3
VI.	63·2	62·5	58·3	51·3	43·0	37·5	37·3	40·9	47·0	52·7	58·5	63·8	51·3
VII.	67·7	65·9	60·1	51·9	42·6	36·9	36·7	41·0	49·4	57·8	64·6	68·7	53·6
VIII.	72·4	71·0	66·0	58·1	48·0	41·3	40·9	47·8	57·3	63·9	70·1	73·4	59·2
IX.	76·1	75·2	70·5	63·7	55·3	48·9	48·7	55·1	62·8	68·1	74·2	77·0	64·6
X.	79·4	78·9	74·1	67·9	60·2	54·3	54·2	60·1	67·5	71·8	77·6	80·4	68·9
XI.	82·2	82·1	76·9	71·1	64·0	58·4	58·4	64·1	71.0	74·8	80·4	83·4	72·2
Noon	84·3	84·1	79·2	73·3	66·7	61·2	61·4	67·0	73·7	76·8	82·2	85·3	74·6
XIII.	85·5	85·5	80·5	74·8	68·5	63·1	63·6	69·2	75·5	78·5	83·5	86·6	76·2
XIV.	85·6	86·3	81·0	75·2	69·4	64·1	64·7	70·3	76·3	79·3	84·0	86·6	76·9
XV.	84·9	85·8	81·0	75·0	69·5	64·1	65·0	70·6	76·5	79·1	84·3	86·4	76·8
XVI.	84·3	84·6	80·2	74·1	68·2	62·6	63·8	69·7	75·4	78·3	83·3	85·6	75·8
XVII.	82·7	82·6	78·0	70·6	62·7	56·3	58·3	65·7	72·7	75·8	81·0	84·0	72·5
XVIII.	80·5	79·7	74·1	65·4	57·4	51·4	52·6	59·0	66·8	71·3	77·5	81·1	68·1
XIX.	76·4	75·5	70·3	62·8	54·9	48·8	49·8	55·4	62.6	67·3	73·0	76·6	64·4
XX.	73·5	72·8	68·2	61·1	53·0	47·3	48·0	53·3	60·2	64·8	70·1	73·7	62·2
XXI.	71·6	71·1	66·4	59·5	51·4	45·9	46·3	51·3	57·7	62·8	67·8	71·5	60·3
XXII.	70·1	69·6	65·1	58·3	50·1	44·7	44·7	49·6	56·1	60·9	65·9	69·7	58·7
XXIII.	68·9	68·6	64·0	57·1	49·0	43·5	43·4	48·4	54·8	59·5	64·2	68·2	57·5
Day.	74·2	73·8	69·1	62·3	54·5	48·8	49·0	54·3	61·0	65·5	70·6	74·4	63·1

* Seven years of observation, 1898—1904,

TABLE 6.—The Diurnal Variation of Relative Humidity at Kimberley (Kenilworth).*

Hour.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Years.
	%	%	%	%	%	%	%	%	%	%	%	%	%
M'nt.	61	63	73	73	67	68	65	57	53	55	49	55	62
I.	63	65	75	75	69	69	68	60	56	57	52	57	64
II.	65	68	77	77	71	72	69	62	58	60	55	59	66
III.	67	69	78	79	72	72	70	63	59	62	58	62	67
IV.	69	70	79	80	73	74	70	64	60	63	60	63	69
V.	71	73	81	82	75	75	70	66	62	65	62	66	71
VI.	72	74	83	84	77	76	72	68	64	65	61	64	72
VII.	64	69	80	84	80	79	74	70	63	58	51	56	69
VIII.	54	59	67	72	70	72	69	60	51	48	43	48	59
IX.	48	51	58	60	58	60	58	49	44	43	38	42	51
X.	43	45	52	53	50	52	50	43	39	38	33	37	44
XI.	38	40	47	47	45	46	45	38	34	34	30	33	40
Noon	35	36	43	43	41	42	41	35	31	32	28	30	36
XIII.	34	34	41	41	37	39	38	32	29	30	27	29	34
XIV.	34	34	40	40	36	37	37	30	28	29	26	29	33
XV.	35	34	39	41	35	37	36	29	27	28	26	29	33
XVI.	36	35	40	42	37	39	38	30	28	29	26	30	34
XVII.	38	39	44	49	48	51	48	36	31	31	28	31	39
XVIII.	41	44	51	58	55	57	54	44	38	37	32	34	45
XIX.	47	50	58	62	57	59	57	47	42	42	37	40	50
XX.	51	54	62	64	59	60	59	49	44	44	40	44	52
XXI.	54	57	66	67	62	62	60	51	47	46	42	47	55
XXII.	56	59	68	69	63	64	62	53	49	49	45	50	57
XXIII.	59	61	71	71	65	66	64	55	50	52	47	52	59
Day	51	54	61	63	58	59	57	50	45	46	42	45	53

* Seven years of observation, 1898—1904.

TABLE 7.—Some Harmonic Constants in the Diurnal Curves of Barometric Pressure and Temperature Variability at Treandrum.

	V_1	V_2	V_3	u_1	u_2	u_3
BAROMETRIC PRESSURE.						
Jan.	18°	163°	15°	·0170	·0479	·0031
Feb.	11	162	34	·0208	·0494	·0035
Mar.	14	162	40	·0214	·0484	·0017
April	15	161	329	·0223	·0458	·0010
May	19	161	117	·0152	·0407	·0003
June	27	159	218	·0121	·0372	·0010
July	41	158	203	·0142	·0363	·0016
Aug.	39	161	250	·0172	·0399	·0013
Sept.	31	165	314	·0218	·0437	·0006
Oct.	31	171	11	·0154	·0466	·0019
Nov.	22	173	10	·0140	·0474	·0032
Dec.	22	171	15	·0186	·0456	·0035
Year.	24	164	11	·0173	·0439	·0012
TEMPERATURE VARIABILITY.						
Jan.	322°	167°	109°	1·809	·846	·392
Feb.	322	168	105	1·787	·949	·403
Mar.	326	173	107	1·632	·881	·376
April	335	175	116	1·411	·784	·299
May	335	176	131	1·151	·564	·244
June	334	167	127	1·020	·512	·229
July	333	168	122	·997	·496	·231
Aug.	333	170	110	1·069	·594	·180
Sept.	335	177	111	1·127	·636	·237
Oct.	337	182	112	1·116	·665	·254
Nov.	338	180	117	1·347	·749	·292
Dec.	326	171	115	1·553	·775	·335
Year.	330	172	115	1·328	·700	·289

TABLE 8.—Some Harmonic Constants in the Diurnal Curves of Barometric Pressure and Temperature Variability at Greenwich.

	V_1	V_2	V_3	u_1	u_2	u_3
BAROMETRIC PRESSURE.						
Jan.	229°	147°	34°	·0099	·0081	·0045
Feb.	124	153	39	·0074	·0098	·0035
Mar.	79	156	44	·0063	·0107	·0015
April	92	156	104	·0080	·0102	·0009
May	61	156	98	·0089	·0089	·0018
June	77	158	101	·0074	·0086	·0023
July	88	160	103	·0061	·0083	·0022
Aug.	84	157	107	·0058	·0099	·0016
Sept.	124	153	31	·0059	·0109	·0011
Oct.	37	149	30	·0071	·0106	·0028
Nov.	250	148	32	·0060	·0089	·0035
Dec.	123	149	33	·0076	·0081	·0046
Year.	23	144	9	·0028	·0100	·0011
TEMPERATURE VARIABILITY.						
Jan.	321°	130°	313°	·484	·480	·280
Feb.	319	134	324	·831	·650	·230
Mar.	322	141	73	1·227	·672	·117
April	328	152	127	1·683	·587	·345
May	330	166	153	1·895	·336	·469
June	330	172	139	2·002	·242	·448
July	329	156	142	2·007	·322	·484
Aug.	328	151	136	1·864	·563	·417
Sept.	330	154	100	1·691	·869	·209
Oct.	331	151	352	1·082	·794	·200
Nov.	324	146	331	·727	·606	·297
Dec.	319	137	318	·436	·413	·254
Year.	327	148	129	1·339	·524	·106

TABLE 9.—Some Harmonic Constants in the Diurnal Curves of Barometric Pressure and Temperature Variability at Kimberley.

	V_1	V_2	V_3	u_1	u_2	u_3
BAROMETRIC PRESSURE.						
Jan.	354°	152°	173°	·0318	·0238	·0036
Feb.	354	148	161	·0329	·0243	·0013
March	351	148	358	·0259	·0244	·0012
April	353	152	360	·0209	·0241	·0038
May	354	154	349	·0190	·0229	·0059
June	345	154	344	·0185	·0217	·0059
July	351	150	349	·0228	·0220	·0063
Aug.	356	154	348	·0247	·0259	·0048
Sept.	360	159	14	·0313	·0279	·0040
Oct.	0	163	83	·0327	·0259	·0010
Nov.	360	160	173	·0368	·0260	·0029
Dec.	358	155	174	·0357	·0241	·0042
Year	355	154	358	·0276	·0243	·0017
TEMPERATURE VARIABILITY.						
Jan.	319°	161°	110°	2·874	1·039	·810
Feb.	319	150	108	2·942	1·274	·681
March	319	145	102	2·832	1·354	·657
April	319	147	93	2·923	1·752	·472
May	318	143	71	3·163	2·161	·290
June	318	141	15	3·185	2·317	·182
July	317	137	28	3·357	2·225	·214
Aug.	317	140	99	3·616	2·099	·501
Sept.	318	147	111	3·652	1·725	·838
Oct.	320	160	129	3·375	1·261	·923
Nov.	321	176	134	3·523	1·048	1·138
Dec.	321	168	124	3·185	·918	·893
Year	320	150	114	3·269	1·568	·654

TABLE 10.—Some Harmonic Constants in the Diurnal Curves of the Variability of Relative Humidity at Kimberley.

	V_1	V_2	V_3	u_1	u_2	u_3
Jan.	313	175	101	4·670	1 915	1·678
Feb.	316	157	104	4.895	2·393	1·383
Mar.	317	147	100	5·348	2·031	1·503
April	318	153	76	5·187	3·422	·868
May	315	145	30	4·770	3·667	·410
June	316	146	334	4·508	3·624	·516
July	316	141	325	4·257	3·095	·590
Aug.	312	149	86	4·551	2·748	·560
Sep.	312	156	103	4·315	2·195	1·140
Oct.	314	175	126	4·489	1·704	1·358
Nov.	314	191	125	4·326	1·804	1·758
Dec.	316	183	114	4·567	1·605	1·609
Year	317	157	101	4·727	2·610	·968

3—ANTICYCLONES AND THEIR INFLUENCE ON SOUTH AFRICAN WEATHER.

By Colonel H. E. Rawson, C.B., F.R.Met.Soc., F.Ph.Soc., Etc.

To anyone holding the clue to South African weather, the study of meteorological problems, not only on this continent but generally over the whole globe, becomes a most fascinating one. South African weather does not present those samples which are so well known in the British Isles, and which are so bewildering by the rapid and inexplicable way they follow one another. Nor are the records which we possess here a mere conglomeration of dry bones, requiring almost a magician's wand to give them life and make them of value. Few as the first-order meteorological stations are in South Africa, they have given us observations of exceptional value and importance, owing to the comparative ease with which they can be interpreted, and an intelligible idea be formed from them of what is going on. We owe a real debt of gratitude to the comparatively large band of volunteers, who supplement our records with local observations, and who help to increase the value of the more precise and accurate data issued by the observatories.

The object of this paper is to submit this clue to you for your consideration, and to lay before you some of the reasons why it is worthy of your attention.

Permanent Anticyclonic Systems.

Before our weather can be intelligently studied, a preliminary knowledge of the seasonal movements of the so-called permanent anticyclones in our neighbourhood is indispensable. For a long time it was held that such systems formed persistent girdles, or belts, of high pressure round the world on both sides of the equator, at about Lats. 25° to 30°. At certain seasons of the year they were said to decrease in intensity and dissipate, to appear once more when the season returned. Thus in winter in the northern hemisphere two well-defined high-pressure systems were found to prevail for quite two months or more at a time over Eastern Siberia and over North America. They gradually diminished as summer approached, and eventually broke up and gave way to cyclones. On the other hand, during summer high pressure prevailed over certain parts of the Atlantic, and especially in the neighbourhood of the Azores, which completely disappeared in winter and was replaced by low pressure, with its destructive storms. The gradual changes from high to low pressure and back again to high pressure were described as "reversals," and were looked upon as continuous processes caused by the seasonal increase and decrease of the sun's heat over the areas where these systems were found to prevail. In 1898 I ventured to combat this view, and I put forward the theory * that the permanent anti-cyclonic systems did not dissipate, or disperse, when they disappeared; but that they gradually moved off to localities where the conditions were more congenial.

*Quarterly Journal of the Royal Meteorological Society, Vol. XXIV., No. 170, July, 1898. *Anticyclonic Systems and their Movements.*

Daily weather charts had made us familiar with the progressive movements of subsidiary, small, anti-cyclonic systems, and, theoretically, there was no reason why the larger and more persistent systems, which had shown themselves capable of resisting for weeks at a time all efforts to break them up, should not move off, rather than disperse, when the conditions became unfavourable. If it should prove that they had a progressive movement, it was natural that their persistence at the extreme ends of their swing should attract attention, for they would appear to linger there, in going and returning, for a longer period than anywhere else in their journey. All available weather charts from 1876 onwards were accordingly examined, and for the 11 years, 1881-91, the mean monthly positions of the cores, or centres, of the Siberian and Atlantic systems were plotted whenever sufficient information could be obtained. The conclusion arrived at was that *there was a distinct progressive seasonal movement.* In the case of the Siberian system this was to the west in the early months of the year, and to the east in the later months, and the persistence which had been observed to occur annually in winter for such a long time over Eastern Siberia was, as anticipated, in consequence of its reaching the extreme end of its swing whilst in that district. The Atlantic system showed a movement on to and off the land, according to the seasons. This fact will be found to be one of special interest to us when we come to consider similar movements off and on to the land in the southern hemisphere. Another important feature was disclosed by the examination. The tracks followed by the Siberian system were not the same each year, nor was the date of arriving at and leaving the extreme winter and summer positions the same. There were good grounds for thinking that the track was deflected north and south of a mean or average track till it reached a maximum, when it gradually returned to the mean again; and, further, that the date of reaching the extreme limits of its swing was sometimes before, and sometimes after a mean or average date. The whole of the movements seemed to be governed by some law of which we have no conception whatever, and in no case were the successive deviations from the mean abrupt. One principle seemed to govern not only the movements, but the formation of the various anti-cyclonic systems. Wherever strong contrasts of temperature were found to be set up from any cause, atmospheric conditions resulted which gave rise to anti-cyclonic systems and largely controlled their movements. It was not difficult to find numerous charts by which to put this to the test. In the "Synchronous Weather Charts of the North Atlantic" for the period August 1st, 1882, to September 3rd, 1883, we have a daily record of the isobars, the isotherms of air and water, and the resultant weather, and with the help of these an examination can be made under the most favourable conditions of anti-cyclones and their movements. Access was accordingly obtained, by leave of the Royal Society, to the original ships' records from which the charts were compiled. The difference between the shade temperature of the air and of the sea *at noon* was plotted, and a comparison made with the completed

synchronous charts of the isobars. A very decided result was obtained. Without exception the anti-cyclones lay over those parts of the Atlantic where the temperature of the sea was lower than that of the air, whereas the cyclonic systems were confined to those parts where the temperature of the sea was higher than the shade temperature of the air. Further, where the strongest contrasts of temperature prevailed, there would be located the core or centre of the anti-cyclonic system. Numerous instances were found in which the core of the system would move away from a locality, losing intensity as it did so, but as it returned to the same spot many days afterwards it would gradually increase to its original intensity, and resume its control over all the weather conditions in the neighbourhood. Applying these results to the progressive movements of anti-cyclones, generally, we have strong reasons for believing that anti-cyclones will by preference move to those localities where they will find the surface temperature of either sea or land colder than that of the air above it; and will follow more readily such a track, from the extreme summer to the extreme winter position, as affords a maximum of these congenial conditions. This is one of the reasons why the track must vary in different years, especially when it leads across mountain ranges on which the snow lies longer in some years than in others, or across districts to which rivers bring the rainfall from a distance, and in varying quantities.

At the Bristol meeting of the British Association in the summer of 1898, Mr. Douglas Archibald brought to notice a set of 20 types of weather systems which had been found to prevail over a great part of the northern hemisphere. They were the result of an exhaustive examination of synoptic charts by Professors Van Bebber and Köppen, and they excited considerable attention, because their authors were able to announce that not only do such types persist for 4 days on an average, but that they exhibit a tendency to succeed one another and to be associated in some cases with one another. In preparing the types, they had analysed charts extending over several years, tabulating the number of days each type had appeared, and the number of times and the manner in which the types had been associated amongst themselves. In this way it was proved that some of the types belonged to certain seasons, and would at some seasons precede, and at others follow, those with which they were most closely allied. On looking through the author's original work for an explanation of these points, I found that they had attempted none. They had made an analysis of very great value and had left any lessons to be drawn from it to others. Coming so shortly after the paper I had read before the Royal Meteorological Society in July of the same year on the progressive movements of anti-cyclonic systems, it had a special interest for me. It offered a chance of testing the theory in a conclusive manner. If the types which were found to precede those they were allied with at one season, proved on examination to return after a sufficient interval and follow the same types at a succeeding season, such a fact would be a strong confirmation of the existence of a regular succession of types controlled

by a persistent force. And if it should further prove that anti-cyclonic systems occupied a predominant place in the types, their progressive movements might be traceable in the charts. *(Here followed 14 lantern slides illustrating the types, and showing that those found to be associated with one another supported the view that the anti-cyclones which controlled the distribution of pressure had a progressive movement).*

Let us now consider the lessons which these types teach us regarding the distribution of pressure which we find prevails near South Africa. The principles governing the distribution are the same in each case. They may be summed up as follows:—

1. The high pressure systems, which are known under the name of the permanent anti-cyclones, have a seasonal migration north and south with the sun.

2. There is a movement off the land on to the ocean in summer; and on to the land from the ocean in the winter, but the Atlantic system seldom entirely deserts its position. It is owing to this system, and to those like it which prevail over the oceans, that the migration north and south with the sun has come to be recognised.

3. At certain times during the winter a continuous belt of high pressure is formed round the globe, which is due to the merging together of all the systems. Each of them, nevertheless, has an individuality which it never loses, and the systems will finally separate and dominate the area to which they belong.

Whether the formation of an anti-cyclone gives rise to that of a cyclone, or *vice versâ*, and what the connection is between the two are still moot points, but it is certain that the two are concomitant, and that where an anti-cyclone prevails a cyclone cannot rage, nor exhibit its objectionable characteristics. It can, and does, however, show by various indications, especially in the sky and by changes of pressure, that it is in existence; and in the writer's opinion it is sometimes superposed above, or partially above, the anti-cyclone. In this way we may account for many of the anomalies which are being disclosed by observations with kites in the upper levels of the atmosphere.

4. Further, these types support the hypothesis that has been advanced, that the changes which are observed in the distribution of pressure are the result of a regular progressive movement of the permanent anti-cyclonic systems from their extreme winter to their extreme summer positions and back again. Secondary and minor anti-cyclonic systems are formed which have irregular movements of their own, quite irrespective of the general progressive movement of the more permanent systems of which they are off-shoots.

SOUTH AFRICAN ANTICYCLONES.

South Africa has two well-defined anti-cyclonic systems near it; one to the west which, like the system over the Atlantic in the northern hemisphere, prevails very generally over the South Atlantic and seldom deserts it entirely, and the other to the east, which will be

referred to as the Australian system. Not having as yet any Marconigrams to report their movements at sea, we must turn for assistance to such charts of pressure as we possess, and to those of currents and hurricanes. In Buchan's excellent set of synoptic charts of atmospheric pressure, the mean positions of these systems appear for each month of the year. The charts were compiled from the best records which were available for the 15 years 1870-84. The movements of anti-cyclonic systems which have been traced in *daily* synoptic charts of the northern hemisphere, help us to fill in the movements of the southern systems from one month to another, as follows:—The Australian system reaches its extreme easterly position off the west coast of that continent about February. From about November to February low pressure has prevailed, for the most part, both over Australia and South Africa. From March to May the Australian system travels westwards over the Indian Ocean, approximately within the parallels of 30° S. to 40° S., always migrating north, as a whole, with the sun. During the same months the South Atlantic system, which had previously been in a central position in mid-Atlantic, has moved eastwards and has extended across South Africa, trying to merge with the Australian system either in April or May. A complete belt of high pressure, similar to what exists during mid-winter in the northern hemisphere, is being firmly established across South Africa. In July the commencement of the return of the two systems to their summer positions begins to be traced on the charts. It is noticeable that just as we saw in the types high pressure systems identifying themselves in winter with certain regions of America and Europasia, so we find in the southern hemisphere certain similar high-pressure systems identifying themselves with regions of South Africa and Australia.

In addition to Buchan's charts, we have a series published by the authority of the Meteorological Council of Great Britain, which brings our knowledge of the movements of these anti-cyclonic systems to the year 1900. When the two are compared we find that in their main features the progressive movements are the same in both, but there is one difference which is of great importance in its bearing upon the second point in our hypothesis regarding the departure of the anti-cyclones from a mean path. In the chart for July the maximum pressure is found in recent years to be lying much further east than previously, and to be to the south-east of Mauritius. The Atlantic system is merged with it right across South Africa, without any centre of pressure or core in mid-Atlantic, as was the case in July up to the year 1894, at any rate. This supports the view which has been advanced, viz., that these systems not only depart from a mean track in going from and returning to their extreme winter and summer positions, but that they sometimes are early, and sometimes late, in leaving them.

I mentioned in explaining the types that in the northern hemisphere winds blow round an anti-cyclone centre in the same way as the hands move round the face of a clock, while in the southern they blow the reverse way, or anti-clockwise. Charts of ocean

currents help us in the following way. If the core leaves the ocean there will be no centre for the winds to blow round. The currents, which are the direct result of the persistent winds belonging to these permanent systems, will slacken if the core remains away a sufficient time, and the charts will record a change in velocity. If the system is far from its mean position we have no difficulty in believing such reports as we are hearing now, that a current like the Gulf Stream is changing its course. Reliable indications of the mean positions of the cores of the Atlantic anti-cyclonic systems in both hemispheres are given by the monthly charts of the ocean currents. There is no necessity, in order to understand the charts, to go beyond what these mighty weather controls—the permanent anti-cyclonic systems of the globe—tell us. In this connection I would bring to your notice the reversal of the Agulhas current, close in-shore along the south coast of Africa, which appears in these charts in certain winter months. As far as my investigation has at present gone, this fact is at once the proof that an anti-cyclone system prevails over South Africa during the months when the reversal takes place, and an indication of the position which that system occupies. I would urge upon the Observatories of Cape Town and Durban to give their attention to this point, for if the connection between the two facts can be established, it would enable warnings to be issued beforehand, which may be the means of saving many a ship. Only recently there was a wreck which was held to be due to abnormal currents along the south coast.

PROGRESSIVE MOVEMENTS.

In the absence of daily synoptic charts to help in tracing the progressive movements of anti-cyclones, we must turn to all the data that have been collected regarding winds, rainfall, temperature, pressure, cloudiness, and humidity.

That there has been some change in the distribution of pressure over South Africa in recent years is shown by the continued drought which has prevailed over some parts, especially the Transvaal and the Orange River Colony. Moreover, we have in Mr. C. M. Stewart's important paper on South African Meteorology, contributed to the Association in 1903, strong proof of the same fact. He pointed out that an investigation of the tri-daily observations made at the Royal Observatory during the period 1896-1900 led him to very different conclusions respecting the prevalent winds, from those given by Dr. Buchan in the *Challenger Report* for the 18 years 1842-55, 1862-65.

A comparison of the two tables, month by month, in which the percentage frequency of the winds from the 8 principal points of the compass is given, indicates that whereas the *Challenger* results make the South to be the prevailing direction of the wind in *every* month of the year, Stewart's analysis shows decided traces of a "monsoon" influence; in that during the winter months, June-August, the prevailing direction is north-westerly, while during the rest of the year it is southerly. Both tables indicate (1) that in every month the

North-West is by far the most frequent wind that blows next to the South, except in December, when the South-East shares the frequency with the North-West; (2) that the South wind is most prevalent in the months December-February.

The hypothesis put forward not only reconciles these different conclusions, but at the same time affords a simple explanation for the recent abnormal drought in South Africa. It also accounts for the position of the core of the anti-cyclonic system so far east in July as the chart of the Meteorological Council, issued in 1900, makes it out to be.

The theory, as applied to the high pressure systems which influence South African weather may be stated as follows. There is a progressive movement of the South Atlantic anti-cyclone on to the land in winter, and off it on to the water in summer, while the Australian system during the same seasons is moving west and returning east. During winter the two systems merge into one another, and together control the whole of the weather. But neither the tracks they follow, nor the extreme positions they occupy, remain the same year by year. In accordance with some law, of which we have only a glimmering at present, the tracks deviate from an average or mean track, and the extreme winter and summer positions differ from an average or mean position, but they do so without any violent interruptions. The departures from the mean appear to be of a continuous character until a maximum is reached, when there is a gradual return to the mean again, to be followed by a similar departure from the mean in the other direction. We can best liken this to the progressive change in declination, which we see in the moon's orbit year by year round the earth, which reaches a maximum on each side of the equator, but always returns to a mean declination. Owing to this departure of the tracks of the anti-cyclonic systems in coming to and leaving the land, there will be a difference year by year in the seasonal winds experienced by the localities traversed. Some districts which have experienced the calms belonging to the centres of the systems will get the winds which belong to the areas north and south of the centre. If the systems are late in going and returning, the winds will show seasonal changes, and if the extreme winter and summer positions are shifted the regions there which are covered by, or which border on, the core, will get an abnormally long season of dry weather. The dry season, which is characteristic of the advent of the anti-cyclone, will be late when the system is late in coming, or early when it is early. Supposing this theory to be correct, the Atlantic system will not pass as near to Cape Town in one series of years as it does in another, and it will be later some years than others. For both these reasons cyclones will be able to approach the Cape with all their characteristic winds and weather; and the winds which prevailed in the spring and autumn months, as the anti-cyclone was passing, would vary slightly from year to year. When the system was following its extreme track, such variations in the winds would be strongly marked. During the winter months June-August the North-westerly winds belonging to the South-westerly quadrant of

the anti-cyclone will of necessity prevail if the system is over the land and to the eastward of the Cape. As its centre passes west of the Cape that station will get the winds of the South-easterly quadrant, viz., South and South-west; and these winds will tend to prevail as long as the centre of the system is out in mid-Atlantic.

The theory of the progressive movements of anti-cyclones was the result of examining thousands of synoptic charts, and in this change in the prevalent winds of recent years, which Mr. Stewart has detected, I see a strong confirmation of its truth.

It is unnecessary to produce any figures to show the great differences of climate which exist between the various parts of South Africa. They are too well known to you. That the Cape has its rainfall in winter, and Natal in summer, is due to the different ways in which these divisions are affected by the two permanent anti-cyclonic systems. The Cape is ruled by the going and coming of the Atlantic system, while Natal owes its dry season to the merging of the Atlantic and Australian systems, and its wet season to their departure. The rainfall of the rest of South Africa is decided by the same controlling forces, according as the path of the Atlantic system lies nearer to, or further from, the districts concerned. The Transvaal and Orange River Colony mostly go with Natal, while the western side of South Africa has practically no rainfall at all in those regions where the Atlantic system dwells longest in its course, but resembles the Cape as we get further to the south, away from the actual track. There are also districts like the comparatively small Knysna Coast District, each with its special rainfall the whole year round, which are said to receive their rain in this way because the winter and summer rains overlap. If we examine one of the most important of these "constant rain" areas we find that the central line through it runs fairly east and west along Lat. 33° 50, with Ladismith and East London at the two extremities. Again, there is no difficulty in tracing this to the lie of the two controlling systems in summer and winter, which allows low pressure to come in between them at this point at one season, and is too far north to keep such systems out at the other.

It is all-important to trace the extent of the progressive movements month by month of the two permanent anti-cyclones, and, as far as our scanty records will allow, the path along which they travel. The few barometer and rainfall records, supplemented by such observations of the winds as are obtainable, are all that we have at present to guide us.

Let us consider the Atlantic system first. On the West Coast, Walfish Bay, Lat. 23° S., is the place with the smallest rainfall, amounting to only 0.31in. a year on the average for 10 years. (Appendix V.) Port Nolloth, in Lat. 29°, has an average of 2.45ins., all of which falls from April to August, and comes "almost wholly from N. or N.W." *

* *Report of Cape Meteorological Commission.*

The rainfall of the Port Nolloth division is the smallest of all the Cape Colony divisions, viz., under 10 ins. a year. The Damara-Namaqua Plateau of German S.W. Africa is over 4000 ft. above sea level. Its mean annual rainfall is 3 to 10 inches, and the station with the least percentage of cloud in South Africa is Springbokfontein in Namaqualand, with only 16.9 per cent.

In the Cape Report for 1901, pp. 183-4, Mr. Stewart has given us a paper on the "Hot Winds of Namaqualand," and has shown that in the months of June, July, and August, 1900, the East wind was the prevalent wind, while from October to March the South was the most frequent. In 1901 winter is reported to have set in at the end of May, and strong, dry and cold East winds followed in June. Mr. Stewart is led to account for the hot east winds by placing an anti-cyclone over the interior of South Africa, and a cyclonic system sea-wards.

All the facts above recorded support the view that I wish to advocate as a first approximation to the truth, and as a working hypothesis, that the core of the Atlantic system has during recent years been passing across Namaqualand along Lats. 26°-27° S., and has then gone slightly N.E., so as to reach the Kalahari region about April. From the Cape reports 1898-1902 the rainfall during those years was found to be a minimum over the area lying from Lat. 23° S. to Lat. 28°-30 S., which points to the core passing approximately along Lats. 26°-27° S., or some 3° to the North of Port Nolloth. Following the path eastwards from Beersheba in Great Namaqualand, we find from observations made at Morokweng in Bechuanaland in 1898, that there was practically no rain from April to October, or somewhat less during these months than fell at Vryburg, Taungs, or Mafeking. In 1899 the records from April to September show the same thing, and a remark that horse-sickness still continued there in April, but was over in May, shows that frosts had begun in the latter month.

The District of Vryburg, Taungs, and Mafeking is, on the whole, the driest during winter of which we have records, the mean fall for the 6 months being Vryburg 3.85ins. and Mafeking 3.57ins. The Mafeking records from 1888 to 1904 show that little or no rain falls from April to October inclusive. And this brings us to the Transvaal, in which we are now fortunate in possessing an excellent Meteorological Observatory, with 290 Rainfall stations, and nearly 300 observers. Twenty-seven stations contribute barometer records. By the courtesy of the Director of the Meteorological Department, Mr. R. T. A. Innes, and thanks to the information afforded by him, I am able to give you (Appendices I.-IV.) the first charts that have been made of the isobars over the Transvaal. They are for the four months February, May, August, and November, and are based upon the four official charts for the same months issued by the Meteorological Council in 1887 for South Africa. They must be considered as provisional only, but they will prove of great assistance to anyone who wishes to test the views that have been advanced in this paper, or to follow them up till they have been proved or disproved.

In the chart for May (Appendix II.) we see that high pressure is firmly established over the Transvaal, and that the centre is lying upon Lat. 27° S. From the distribution of pressure it is evident that the centre is already to the east of the Colony, and that it has merged with the Australian system coming from the east. We can further test this point by examining the barometer readings at the various Transvaal stations for the first 6 months of 1905, as given in the recently-published second annual report of the Transvaal Meteorological Department. Taking the stations from west to east we have the following monthly means :—

BAROMETER READINGS—MONTHLY MEANS.

1905.	Marico District, 9h	Klerksdorp. 8h	Johannesburg, mean of day,	Vereeniging. 9h	Pretoria. 8h	Potgietersrust. 9h	Barberton. 7h 30	Mbabane. 9h
Jan...	26·143	25·719	24·275	25·372	25·655	26·335	27·107	25·968
Feb. .	·163	·775	·285	·382	·667	·351	.123	·980
Mar.	219	·792	·334	·430	·718	·411	·166	26·020
April	**·280**	**·849**	**·381**	**·485**	**·777**	**·463**	**.231**	**·073**
May .	·269	·821	·340	·460	·750	·454	·203	·038
June .	·240	·799	·302	·430	·716	·428	·163	25·988

All these records attest the same fact, whether they are made at stations in the North, South, East, or West of the Colony, viz., that high pressure arrived in 1905, in the month of April, and that the barometer fell as it passed on. The pressure is highest in that month at every station in the Transvaal.

Now let us turn to the Australian Anti-cyclone, and see what progressive movements can be traced from the information that is available. The records of the Royal Alfred Observatory, Mauritius, give us what we require. It is in Lat. 20° 5 S. and Long. 57½° E. It is somewhat north of the normal track of the Australian system, but the records bear the unmistakable traces of its influence, as it passes westwards and returns eastward during each year. In the Report for 1900 the following mean monthly barometer readings are given for 26 years :—

BAROMETER READINGS.

Monthly Means. 26 years.	Jan.	Feb.	Mar.	April	May	June
	29·751	·734	·769	·818	·888	·964
	July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	30·008	**30·010**	29·998	·939	·878	·814

The minimum occurs in February, which we have already found to be the month when the anti-cyclone is in its extreme summer position near Australia, and consequently furthest from Mauritius. It then

turns and comes west, causing a gradual rise of the barometer readings, and as the centre passes to the south during May the mean variation of pressure is greater than in any other month in the year. That this rise of pressure is due to the anti-cyclone is further confirmed by an examination of the tracks of the hurricanes which have come into the vicinity of Mauritius, and have been recorded at the Observatory for a great number of years. I am not aware that any connection between the two has ever previously been pointed out, but it must be apparent that if the anti-cyclone has a regular progressive movement towards and away from Mauritius, the number of hurricanes recorded must decrease month by month as the anticyclone approaches, and must cease when it lies near enough to ward them off. This decrease is just what is found to take place, and from June to October they cease altogether. Moreover, the tracks the hurricanes will follow each year will be controlled by that of the anti-cyclone, and they will take a straight or parabolic course, according to the lie of the isobars of the anti-cyclonic system. In these charts we possess a direct indication of the position of the system each month, and a very strong confirmation of all the views that have been advanced regarding its progressive movements from Australia to Africa and back again.

We have previously seen that the Atlantic system is fast approaching the East Coast of Africa during the month of May, and merging with the Australian. This must also affect the barometric pressure at Mauritius, and as the two systems become established and migrate north with the sun up to the June solstice, the barometer must continue to rise. (Appendix VI.) The chart of the isobars for July, issued by authority of the Meteorological Council, to which reference has already been made, places the centre of the high pressure prevailing over South Africa, not far from Mauritius. The mean monthly barometer readings for July and August are in consequence the highest of the year. From September to about February the anticyclone is receding, and the barometer falls gradually. The Mauritius records show just the rise and fall of barometer which our theory requires, and are all in favour of it. But there is a further test that can be applied. In the records of the Natal Observatory at Durban we possess from 1885 onwards meteorological observations of the greatest importance in this inquiry. They indicate that secondary anti-cyclonic systems frequently pass from west to east across Natal, especially from May to August, and from observations made in the Sydney Government Observatory such systems are believed to reach that place after an unbroken journey. This supports the view that the atmospheric conditions from end to end of this track are favourable to the progressive movements of anticyclonic systems.

During the 10 years 1890-99, the mean moisture in the atmosphere at Durban during the several months in grains per foot cube was as follows :—

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
7·3	7·5	7·3	6·3	5·2	4·5	4·4	4·9	5·4	5·9	6·5	7·0

These figures clearly indicate the decrease in moisture in the winter months, and, coupled with the absence of rain from Natal during the winter, they strongly support the view that an anti-cyclonic system is present, and is impressing its well-recognized characteristics upon the district. An analysis of all the records for the 15 years 1885-99 shows that a ridge of high pressure is first established in April, and out of the last 10 years of that period only two are exceptions to the rule that there is an increase of pressure in April over March, and in May over April. The exceptions are in 1891 and 1893. The mean monthly barometer readings for the period are :—

Jan.	Feb.	Mar.	April	May	June	July
29·980	30·008	30·047	30·119	30·172	30·229	30·232
	Aug.	Sept.	Oct.	Nov.	Dec.	
	30·214	30·140	30·092	30·023	30·000	

The mean pressure differences from month to month reach a maximum in March-April and in August-September, and it is in these months that the arrival and departure, respectively, of the anti-cyclonic systems belonging to the Atlantic and to the Pacific are making their influence felt upon the barometric pressure. The differences amount to 0.072in. between March and April, and to 0.074in. between August and September. These are large variations when we find that during 15 years the greatest departure of any annual mean from the mean for the whole period is only 0.043in., and that in 15 years the range of the barometer, as shown by the maximum and minimum records, was only 1.331ins. The highest reading ever recorded in the annual reports is 30.838ins., and the lowest 29.507ins. It is quite in conformity with these results that the dry season in Natal commences when the anti-cyclone becomes established about the end of April, and ends when it leaves about the beginning of September. In Buchan's charts for August and September we see that the secondary anti-cyclonic system, which has persisted over Natal from May to July, has gone, and that the Australian and Atlantic systems are beginning to separate, and to depart to their summer position. The gradual fall in the mean monthly pressure at Durban is the result. The valuable records kept at this Observatory of rainfall, winds, pressure, and other meteorological elements are full of details supporting the theory of the progressive movements of the two systems, but we must leave them and pass on to the final point to which space will permit a reference. (Appendix VII). In Buchan's "Rainfall of South Africa" he discusses the observations made from 1885 to 1894, and publishes maps which Mr. Struben reviews in the Report of the Cape Meteorological Commission, with the fuller information available up to 1897. The facts that are given, and the conclusions arrived at, are made quite intelligible when looked upon as the direct results of cyclonic systems which are controlled by the steadily-moving Atlantic and Australian anti-cyclones. It was found that the rains borne from the S.E. are at a minimum in August, and are confined practically to the coast, while the rains borne from the S.W. at the same period are at their maximum. After August the S.E. borne

rains increase in intensity and advance further and further inland till January, when they are at their maximum and extend almost to the West Coast. During the same period the S.W. borne rains have been steadily decreasing in intensity and receding, as it were, before the advancing S.E. rains, till in January they are at a minimum, and are confined practically to the extreme South Coast.

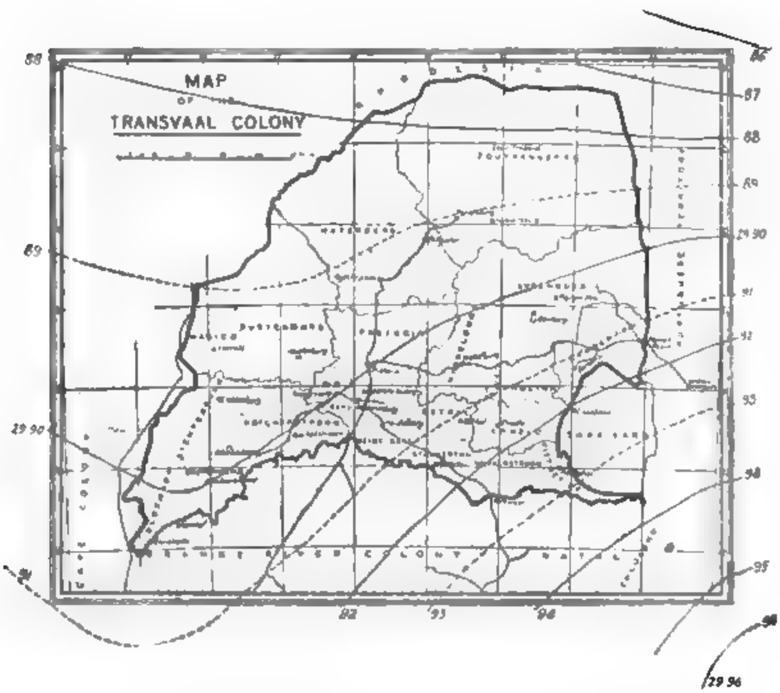
After January the S.E. borne rains steadily decrease in intensity and recede towards the east till July, when they are at a minimum, and are confined to small areas near the S.E. Coast. During the same period the S.W. borne rains have steadily been advancing towards the east and increasing in intensity till the maximum is again reached in August. The facts are summed up by saying that "summer rains" advance from the S.E., commence about August, increase in intensity and scope till January (height of summer) and decline from then till August. In direct opposition, "winter rains" advance from S.W., are at a minimum in January, increase in intensity till a maximum is reached in August, and then decline till January. In this description we have a very complete picture presented to us of the thrusting backwards and forwards of rain-bearing systems with their characteristic S.E. or S.W. winds, and of the consequent increase and decrease of the rainfall over the areas which they traverse. If we imagine the Atlantic and Australian anti-cyclones to have any influence in the matter—powerful weather-controls as we know all such systems to be—it requires nothing more than to allow that they have a seasonal progressive movement in order to make the above variations in South African rainfall quite clear to us.

We have now passed in review many of the prominent characteristics of our weather on this vast continent, and have found that whatever portion of it we examine, and whether we consider the winds, rainfall, pressure, clouds or humidity which prevail over it, they all support the theory which has been advanced, that they are under the direct control of the two great anti-cyclonic systems, and are influenced by their progressive movements. Before long we may hope to see daily charts illustrating their movements on to the land in winter, and off it on to the ocean in summer, enabling reliable forecasts to be made of such important points as the arrival of the dry and wet seasons, and of the frosts, all of which depend on the anti-cyclonic movements. When that day arrives we may look forward with confidence to discovering the connection between the winds experienced here, and the monsoons in India, with their all-important effects on the rainy season. It is in the hope of hastening that day, and of contributing, perhaps, towards the solution of some of the problems which are at present obscure, that this paper has been prepared.

Appendix I.

PROVISIONAL CHART OF ISOBARS.

FEBRUARY.



Buchan.—His chart gives the isobars as lying SSW to NNE. The SE is nearly 29·86 ins., the North 29·83. At Pretoria the pressure is 29·846 ins.

Jan.—His isobars lie NNE to SSW across Transvaal, 29·77 on West and 29·82 on East side. At Pretoria pressure is 29·79 ins.

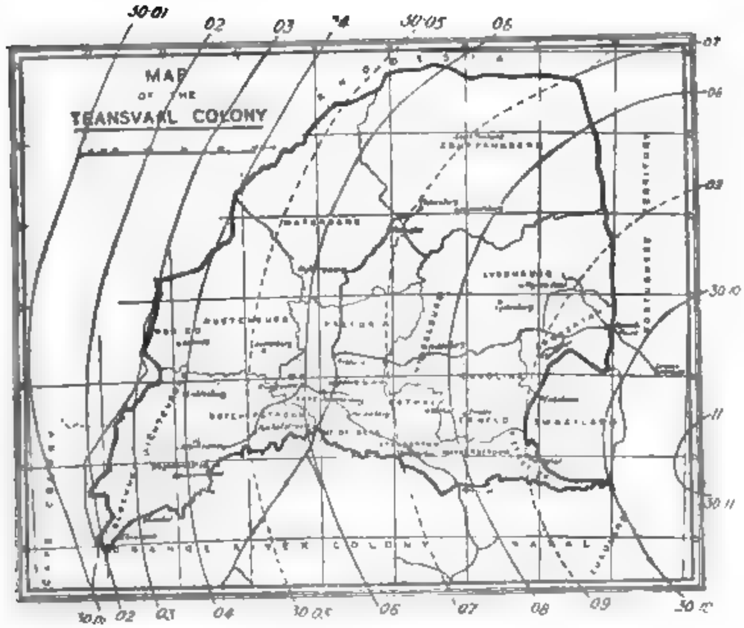
Mar.—His isobars lie more SW to NE and pressure varies from 29·93 in SE to 29·88 in North. At Pretoria pressure is 29·91 ins.

Ap.—His isobars lie from NW to SE across Transvaal, the southern ones becoming nearly E to W (30·04). The Northern isobars are parallel and regular (29·99 the extreme NE one). At Pretoria pressure is 30·025.

Appendix II.

PROVISIONAL CHART OF ISOBARS.

MAY.



Buchan.—His chart shows a little of the Australian anti-system in SE corner, isobar being convex to Transvaal, 30·11 ins In SW corner the Atlantic anti-system is also over Transvaal, 30·12 to 30·15, the latter reaches as high as Johannesburg and the former nearly to Nylstroom and as far east as Ermelo. In the N the isobars lie E and W approximately, pressure ranging from 30·06 above Pietersburg to 30·00 in S. Rhodesia, 30·14 at Pretoria.

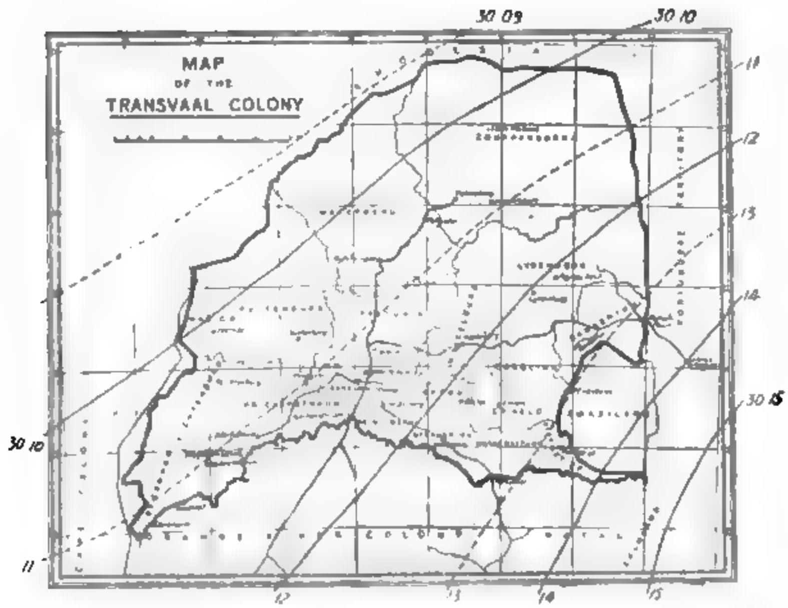
June.—The Atlantic system is over all Transvaal, its axis lying SW to NE, varying from 30·22 over Standerton and Wakkerstroom districts to 30·20 over the rest of the Colony. At Pretoria 30·21 ins

July.—The Anti-system has moved W as a whole, and the greatest (30·24) pressure is over Potchefstroom, Wolmaranstad districts, not reaching to Johannesburg. The isobar 30·22 reaches to Potgeiter and round to Ermelo. The rest is enclosed by isobar 30·20. The axis still lies SW and NE 30·23 at Pretoria.

Appendix III.

PROVISIONAL CHART OF ISOBARS.

AUGUST.



Correction for Gravity – ·050.
„ „ Sea level + ·010.

Buchan.—The trend of his isobars 30·14 and 30·15 agrees closely with the above, but 30·15 lies where 30·14 is shown here. The rest of his isobars are more parallel to a latitude than shown here Over the Transvaal pressure is from 30·10 in North to 30·16 in SE.

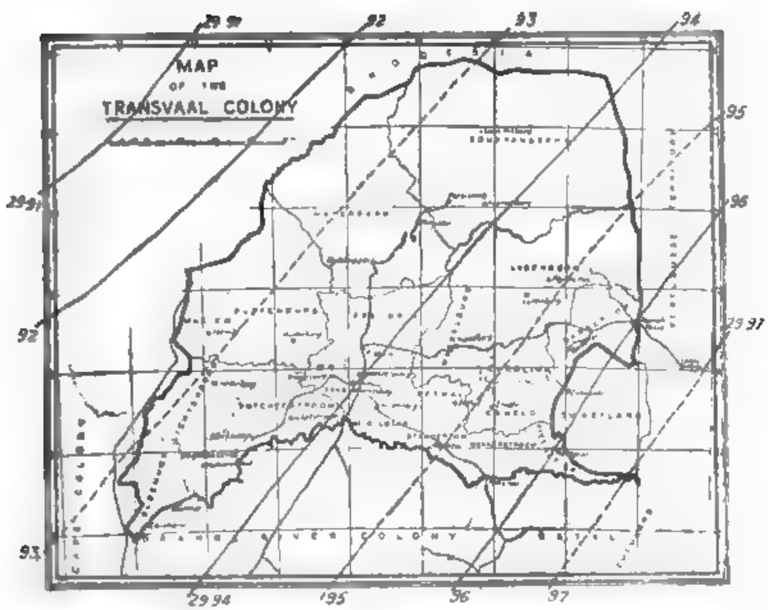
Sept.—His isobars closely follow the above, pressure is from 30·06 in the NW to 30·09 in SE. At Pretoria it is 30·075 ins.

Oct.—His isobars lie from SW to NE across Transvaal, and pressure is from 29·96 in NW to 29·99 in SE. At Pretoria it is 29·978 ins.

Appendix IV.

PROVISIONAL CHART OF ISOBARS.

NOVEMBER.



Buchan.—The trend of the isobars is the same, but 29·92 in his chart lies close to and parallel with 29·97, and 29·82 with 29·92. Pretoria in his chart lies on 29·86.

Dec.—The Transvaal is in the southern extremity of a Cyclonic system, the pressure varying from 29·81 in the N to 29·84 in the S, the centre being somewhere due north of Pretoria. Pressure at Pretoria is 29·825 ins.

Appendix V.

Walfish Bay, Lat. S. 22·56°, Long. E. 14·30°.

RAINFALL.

	1899. inch.	1900. inch.	1903. inch.	1904. inch.	Remarks.
January ...	...	0·00	...	0·00	The area of least rainfall lies between Walfish Bay and Lat. 28°. The rainfall in 1900 at 11 stations, rendering returns, averaged under 4 ins.
February ...	...	0·00	0·34	0·00	
March	...	0·00	0·00	0·00	
April	0·00	0·009	0·00	0·00	
May	0·00	0·010	...	0·00	
June	0·00	0·00	0·00	0·00	
July	0·00	0·00	0·00	0·00	
August	0·00	0·00	0·00	0·00	
September ...	0·00	0·00	0·00	0·00	
October ...	0·40	0·100	0·00	0·00	
November ...	0·00	0·00	0·00	0·00	
December ...	0·01	0·00	0·01	0·00	

Appendix VI.

Royal Alfred Observatory, Mauritius.

Barometric Pressure, Departure from Average in each Month of the Year.

Month.	1899. inch.	1900. inch.	1903. inch.	1904. inch.	Remarks.
January ...	−·027	+·056	−·053	+·063	The recovery from a negative wave which culminated in December, 1902, persisted throughout 1903, until October, when pressure returned to the normal. This wave was the greatest on record, the defect in pressure for 18 months being 0·519 in. The next greatest on record was from Aug. 1875 to Feb. 1876, the total defect being 0·399 in. From Oct. 1903 to the middle of 1904, pressure increased steadily relatively to the normal.
February ...	−·032	+·030	−·015	−·015	
March ...	−·019	−·003	−·059	−·049	
April... ...	−·003	−·008	−·015	−·004	
May	−·005	−·009	+·003	+·006	
June	−·004	−·013	−·037	+·062	
July	+·067	+·030	−·015	+·002	
August ...	+·055	+·021	−·011	+·033	
September ...	+·018	+·011	−·005	+·043	
October ...	+·003	+·050	−·000	−·029	
November ...	−·010	+·018	+·013	+·066	
December ...	+·032	+·070	+·012	+·018	

NOTE.—Barometric pressure.—The Report for 1904 says, 'The pressure abnormalities since the end of the year 1901 have been remarkable both for amplitude and regularity. The curve fell generally from + 0·042-in. in September, 1901 to − 0·090-in. in December, 1902; rose to + 0·062-in. in June, 1904, and then decreased to − 0·036-in. in January, 1905.' Viewed in connection with a progressive movement of the Australian Anticyclone to and from South Africa in each year, an explanation of such abnormalities, or 'negative and positive waves' is given by the theory that has been advanced. The anticyclone does not follow the same path to and fro each year, nor does it pass Mauritius at exactly the same time. This will affect the barometer in the way indicated by these so-called 'waves.' The rainfall is very significant during the period 1880 to 1903, and points to a varying influence from a high pressure system, which is ever altering its relative position with respect to Mauritius, while its movements continue to be progressive and regular. The drought of 1880 was associated with an exceptionally well marked positive pressure wave, and that of 1885-6 with the recovery of pressure after a feeble negative wave, *i.e.*, in 1880 the anticyclonic system was near Mauritius at the time of the rains and influenced the fall, while in 1885-6 it was returning to its normal path after a deviation which allowed the rain-bearing system to come in. The drought of 1889-90 was synchronous with a feeble negative pressure wave, following a well marked positive wave, while that of 1893 was synchronous with a well marked positive pressure wave between two equally well marked negative waves. From 1896 to 1898 the rainfall abnormality curve was slowly recovering from a steep minimum, while the pressure curve was falling steadily. What more suggestive record could there be of a gradual retrocession of the high pressure

system during this period? The severe drought of 1899-1901 was associated with an irregular pressure curve usually above normal, pointing to a return of the system gradually to its mean path nearer Mauritius. Lastly, during 1903 the rainfall abnormality curve showed no well marked waves though there was a gradual decrease in the amplitude from September to the end of the year, accompanied by a gradual rise in the pressure curve.

The mean monthly rainfall during 25 years has been tabulated, and amounts to 48·36 inches for the year. Only 11 inches of this amount fall from June to November inclusive; 22 inches fall in January, February and March.

Appendix VII.

Natal Observatory, Durban.

Monthly Mean Barometric Pressure, reduced to Sea-level, corrected to 32° F., derived from 9^h and 15^h readings.

	1899. inches.	1900. inches.	1901. inches.	1902. inches.	1903. inches.	1904. inches.
January	29·965	29·968	29·913	29·966	29·966	29·976
February	·988	30·069	30·020	30·033	30·065	30·002
March	30·067	·040	·070	·026	·021	·044
April	·157	·116	·118	·035	·054	·066
May	·283	·131	·159	·179	·069	·167
June	·336	·293	·313	·141	·193	·201
July	·255	·197	·235	·191	·252	·274
August	·160	·157	·251	·131	·191	·181
September	·188	·187	·197	·123	·263	·190
October	·069	·042	·160	·165	·044	·029
November	·085	30·013	29·998	·027	·009	·024
December	29·993	29·976	·975	·052	29·991	·060

NOTE.—The readings in 1899 were exceptional. The mean pressure for the year was 30·129 ins.—the record for 33 years. The pressure in March is noted as exceptionally high, but it was surpassed in March, 1901 and 1905. The readings in February and March point to an early establishment of high pressure, which is probably attributable to the approach of the Atlantic system across South Africa.

4.—THE BAROMETER IN SOUTH AFRICA.

By R. T. A. Innes, F.R.A.S.

1. Annual Variation of the Pressure over South Africa.
2. Movement of Atmospheric Disturbances across South Africa.
3. Reduced Monthly Readings of the Barometer :—
   (a) Royal Observatory, Cape of Good Hope, 1841-1905.
   (b) St. Helena, 1840-1847.
   (c) Natal Observatory, etc., Durban, 1873-1905.

1. Annual Variation of the Pressure over South Africa.

The history of the barometer in South Africa leaves something to be desired. We have to be thankful to the Cape Meteorological Commission for the vast number of monthly means of pressure which it has collected and published in its yearly volumes. Outside of this series, there is not much to work on; in fact, away from the coast, there are practically no useful observations available. The references given in Table 1 will show the sources of the material that were available. It is well-known that the pressure of the atmosphere (measured by barometers) varies constantly, both irregularly and regularly. The irregular variations are due to the passage of areas of low or high pressure, commonly called cyclones and anticyclones; the regular variations are of an annual and diurnal nature, and may be ascribed to the direct action of the Sun. The regular variations are (1) the double diurnal variation by which, in the mean, the barometer is highest at 10 and 22 hours, and lowest at 4 and 16 hours, and (2) the annual variation, by which in South Africa, the barometer is highest in winter and lowest in summer. The regular variations give rise to the diurnal and seasonal winds, but at any particular time, these regular winds may be displaced by the passage of areas of low or high pressure. To compare readings of barometers taken at different places, we need to know, first of all, the errors of the barometers and their altitudes above sea-level. For many of the barometers near the coast, this information is available, but away from the coast, it is not so. I believe that the only barometer in the interior of South Africa whose height is known by geodetic levelling is at the Johannesburg Observatory. Until we know the heights and index errors of many barometers properly distributed over South Africa, it is impossible to compare readings at different places or to draw isobars or lines of equal pressure over the country. The various geodetic surveys carried out under the direction of Sir David Gill make it possible to fix the heights of a considerable number of barometers with precision, and this is a work that must be undertaken at an early date. I can promise to do it for the Transvaal soon, and I hope that my colleagues in the other colonies will do their share as far as possible. We can, in the meantime, say nothing about the

absolute pressures over South Africa. The isobars on the following map are founded on observation as far as the coast is concerned, but on theory across the continent.

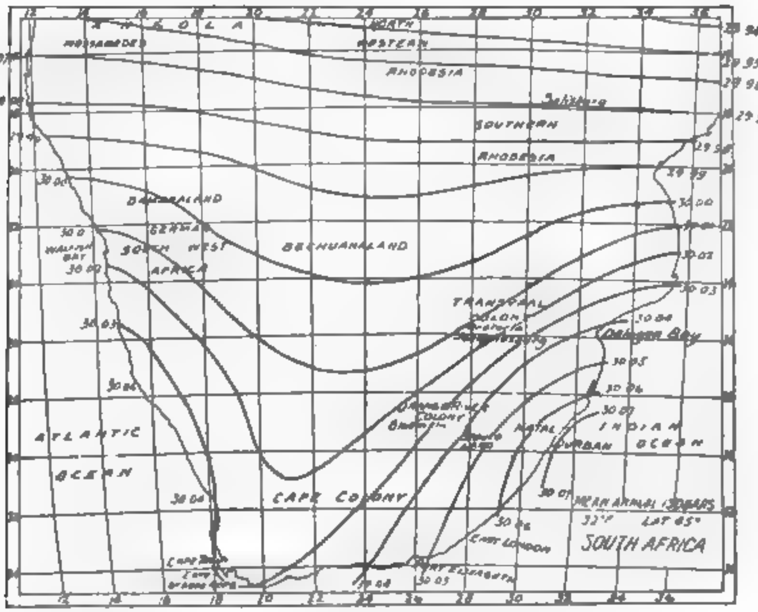


Fig 1. Mean Annual Isobars, S. Africa.

The diurnal variation requires either hourly observations or continuous records. I believe that hourly readings are taken at one or two of the ports in Portuguese territory, but they are not published. The only records available are those made by our indefatigable South African meteorologist, Mr. J. R. Sutton, at Kenilworth, near Kimberley, and those made at the Johannesburg Government Observatory. Some sixty odd years ago, hourly observations were taken at the Cape and St. Helena,—these are referred to later on. Hourly readings taken from the continuous records of Richard or similar barographs, and checked against two daily readings of mercurial barometers, are badly wanted for more places south of the equator.

The annual change of the barometer is the only element which permits useful study at the present time, and even in regard to it, there are difficulties. The barometers in common use in South Africa are of the Kew pattern. This model suffers from several serious defects; one of these is the variable index error, which is apt to change each time the barometer is moved, but a more important one is that sometimes the mercury sticks and remains stationary for weeks at a time. It is then necessary to invert the barometer and re-hang it before it will perform properly; a smaller defect is that the

temperature correction of Kew barometers does not depend on the mercury and scale alone, but also on the size and material of construction of the cistern, for which no allowance has been made. In countries of high latitude where the fluctuations of pressure are considerable, Kew barometers may be useful, but in South Africa, where the range is small, we must rely on the Fortin pattern and educate observers in its use. With the observations available there are many breaks and very often very large errors. Practically all the observations published by the Cape Meteorological Commission have been extracted and tabulated by me, and the best of the material (where a choice exists) used. In some cases where there are very few stations and very few years' records, we have perforce had to use them. The first result of an inspection of these sets of observations is to show that the annual variation of the barometer over the whole of South Africa and the adjoining regions consists of a well-marked single oscillation, pressure being greatest in winter and least in summer. The only possible exception to this rule is with Swakopmund in German S.W. Africa, in which case there is a slight divergence which would perhaps disappear if a longer period of observations than 4 years were available. The annual variation is, in the main, an almost pure sine-curve, that is, it can be represented by an expression of this form

$$A \sin (t+\theta)$$

in which A is the difference of the highest or lowest reading from the mean of the year. The time of the year is represented by t as follows:—January 15th $=0^\circ$, February 14th 30°, and so on; θ represents the difference of phase. A few examples will make the meaning of this formula quite clear. If for a given place we have

$$\text{Bar} = \text{mean height} + 0.112 \text{ inches } \sin (t + 270^\circ$$

it tells us that in the middle of January when $t=0^\circ$ and $\sin 270^\circ - 1$ that the barometer will be 0.112 inches under its mean height, and as $\sin (t+\theta)$ cannot be greater than $+$ or -1, we know that it is then at a minimum. In the middle of March when $t=90^\circ$ $\sin (t-270^\circ)$ will be zero, so that the barometer is then at its mean height. If, however, θ is not 270° but say 255° it would mean that the minimum does not take place when $t=0^\circ$, but when it is $=15^\circ$ or about 15 days after the middle of January.

Table 1 gives an analysis of the annual variation for a large number of places in and near South Africa. The figures for the heights above sea-level and the mean-barometer are to be considered approximate. An inspection of the table shows that the first term having a period of a year is by far the most important. A very natural question in regard to such an analysis as this, is what are the value of the figures, to what extent are they uncertain owing to fluctuations from the mean, etc.? To answer this question, the analysis has been made for 6 decades for the Cape Observatory,—in this case the extreme divergencies are:—of maximum phase 3 days, of amplitude 3/1000ths of an inch. The differences amongst the second and third terms are larger, but the substantial reality of these terms cannot be doubted.

TABLE I. PERIODIC VALUES OF THE SERIES REPRESENTING

a. Reduced to 32° F. and Sea-level. *b*. Reduced to 32° F., Sea-level and Gravity of 45° Lat.

Place.	Latitude.		Height above Sea-level.	Mean Barometer	A_1	θ_1	A_2
	°	′	Feet.	Inches.			
Leh	+34	10	11,503	19·67	33	181°	60
Chakrata...	+30	40	7,022	23·22	69	109	51
India (mean)	+30	0	[illegible]	29·84	310	94	70
Darjeeling	+27	3	7,376	22·96	68	127	43
St. Louis, Senegal ...	+16	2	[illegible]	29·94	11	140	22
Aden	+12	45	94	29 76*c*	162	94	31
Perim	+12	37	201	29·69	165	96	26
Colombo	+ 6	56	[illegible]	29 82	43	112	15
Porto Novo, Dahomey..	+ 6	28	22	29·85	52	242	20
Mayumba, F. Congo ...	− 3	25	213	29·77	66	236	24
Kwai, Germ. E. Africa	− 4	45	5,280	24·83	60	254	13
Zanzibar	− 6	10	73	29·92	98	250	13
Daressalam	− 6	49	40	29·94*b*	109	252	15
Mozambique	−15	[illegible]	13 & 35	29·97*b*	137	258	8
Zomba	−15	23	2,948	29 97*a*	122	279	25
St. Helena	−15	57	1,764	28·22*c*	58	251	20
Salisbury	−17	48	4,700	25·33	87	271	6
Tamatave, Madagascar	−18	10	10	29·99*b*	160	250	[illegible]
Tananarive „ ...	−18	55	4,460 & 4,590	25·61	89	254	7
Beira	−19	50	50	30·09	184	277	26
Bulawayo	−20	0	4,469	25·75	92	280	[illegible]
Mauritius	−20	6	181	29·88	139	244	5
Swakopmund	−22	56	(8)	30·02	86	275	16
Pietersburg	−23	56	3,950	25·99*c*	97	278	6
Lourenzo Marques ...	−25	56	...	30·06*b*	119	273	...
Johannesburg	−26	11	5,925	24·36*c*	69·	288	6
Kimberley	−28	43	4,042	26·08	114	280	10
„	−28	43	4,042	26·06	112	285	7
Bloemfontein	−29	7	4,518	25·57	95	279	9
Port Nolloth	−29	14	25	30·03	123	258	19
Durban	−29	51	250–262	30 14	129	275	6
„	−29	51	250–262	30·10	118	273	10
Philippolis	−30	12	4,600	25·59	99	287	[illegible]
Kilrush	−30	28	6,850	23·87	60	286	11
Aliwal North	−30	41	4,330	25·77	103	286	10
Umtata	−31	35	2,400	27·73	96	280	8
„	−31	35	2,400	27·70	104	279	9
Wagenaar's Kraal ...	−31	48	4,500	25·89	[illegible]	[illegible]	4
Brakfontein	−31	52	4,000	26·12	93	274	9
Queenstown	−31	54	3,500	26·46	83	281	[illegible]
Clanwilliam	−32	10	245	29·77	135	256	12
Graaff Reinet	−32	16	2,504	27·50	94	264	[illegible]
Sutherland	−32	25	4,900	25·31	71	283	33
Stutterheim	−32	34	2,740	27·30	86	281	[illegible]
Somerset E.	−32	44	2,400	27·59	88	276	3
King	−32	52	1,314	28·72	106	276	2
East London	−33	[illegible]	33	30·04*a*	106	270	[illegible]
Grahamstown	−33	18	1,800	28·17	88	269	4
Ceres	−33	22	1,498	28·55	98	270	13
Dunbrody	−33	30	250	29·85	119	[illegible]	6
R. O., Cape, 1841-50 ...	−33	56	37	...	111	262	11
„ 1851-60 ...	−33	56	37	.	110	262	7
„ 1861-70 ...	−33	56	37	...	113	261	4
„ 1871-80 ...	−33	[illegible]	37	...	114	262	6
„ 1881-90 ...	−33	56	37	...	114	259	[illegible]
„ 1891-1900 ...	−33	56	37	...	113	263	12
Port Elizabeth	−33	58	181	29·88	99	267	4
Table Mt., Devil's Peak	−33	58	1,430	28·57	81	262	7
„ Disa Head ...	−33	59	2,496	27·51	68	270	6
Mossel Bay	−34	11	105	29·99	95	252	6
Simonstown	−34	12	12	[illegible]	100	258	12
Cape St. Francis ...	−34	[illegible]	20	[illegible]	94	266	3
Cape Agulhas	−34	50	55	30·00*a*	81	[illegible]	3

THE ANNUAL VARIATION OF THE BAROMETER.

c. Reduced to 32° F. and Gravity of 45° Lat. Unmarked, reduced to 32°F. Unit = 0·001 in.

θ_2	A_3	θ_3	Number of Years.	Reference.
242°	11	187°	20	Indian Met. Mems.
252	3	129	25	"
242	9	118	...	W. L. Dallas, Quat. Jour., 1906, April.
252	5	169	35	Indian Met. Mems.
[illegible]	3	44	11	Paris, Bureau Central Met.
235	4	65	22	Indian Met. Mems.
[illegible]	2	151	10	" "
29	7	8	33	" "
59	12	33	4	Paris, Bureau Central Met.
75	10	9	2	" " "
97	10	71	3	German Met. Publications.
81	10	24	21	Indian Met. Mems.
80	11	42	7	German Met. Publications.
162	1	304	8	Portuguese Authorities, and Paris.
94	1	304	3	Scientific Dept., British Central Africa.
88	5	204	7	See p. 110 *et seq.*
96	3	76	6	Cape Met. Com.
180	6	355	6	Paris. Bureau Central Met.
158	6	114	11	" " "
116	18	184	3	Portuguese Authorities.
[illegible]	5	58	...	Goetz.
187	8	255	26	Observatory, Mauritius.
75	[illegible]	346	4	Met. Zeitschrift. Includes one year Walfisch Bay.
66	11	223	2½	Trans. Met. Dept.
...	...	...	2	Port Capt in.
87	5	207	8	Trans. Met. Dept., C.M.C., &c.
100	10	19	9	C.M.C.
[illegible]	9	275	...	J. R. Sutton.
[illegible]	10	333	19	C.M.C. & J. Lyle.
130	8	254	7	" "
69	11	39	10	See p. 119 *et seq.*
62	7	310	. .	J. R. Sutton.
114	5	304	8	C.M.C.
75	24	23	3	"
80	9	87	10	"
115	8	50	10	"
110	4	307	...	J. R. Sutton.
192	18	50	5	C.M.C.
102	11	310	[illegible]	"
[illegible]	2	339	18	"
[illegible]	10	13	10	"
[illegible]	[illegible]	297	11	"
89	26	214	5	"
[illegible]	10	38	10	"
287	8	341	18	"
153	8	23	10	"
132	9	52	10	"
56	10	328	20	"
149	8	85	10	"
78	7	165	18	"
107	2	0	9	See p. 95 *et seq.*
63	4	245	10	"
128	8	240	10	"
198	[illegible]	332	10	"
108	11	269	10	"
165	8	6	10	"
171	10	42	10	C.M.C.
202	11	35	6	"
192	16	15	7	"
184	12	32	10	"
173	9	23	10	"
184	[illegible]	39	10	"
[illegible]	9	26	10	"

Confining our attention for the moment to the chief term and to fix our ideas, let us suppose that it is due to the Sun's action,—that as summer comes on the air is expanded by the solar heating of the ground or sea and pressure thereby diminished and that as winter comes on the opposite effect takes place. On such an hypothesis, it is evident that the ground ought to get warm more quickly in spring than the sea and cool more quickly in autumn. This would be a ground effect and to a certain extent independent of altitude as long as the ground was level or plateau-shaped, but that at quite moderate elevations on isolated mountains, and to a lesser extent on mountain ranges, the local heating should have no effect as there is an escape on all sides for the heated air. It will be seen that the figures conform very closely to this hypothesis. At ocean or coast stations the angle is always smaller than at inland stations :—

Coast		Inland.	
Zanzibar	250°	Zomba	279°
St. Helena	251	Salisbury	271
Tamatave	250	Bulawayo	280
Mauritius	244	Kimberley	282
Mossel Bay	252	Stutterheim	281

These figures show that the extreme readings at continental stations occur nearly a month earlier than at the coast.

The decrease of amplitude on mountain stations is shown by the following examples :—

Cape	0.113 inches	37 feet alt.
Devil's Peak	0.081 ,,	1,436 ,,
Disa Head	0.063 ,,	2,496 ,,
Tamatave	0.160 ,,	10 ,,
Tananarive	0.089 ,,	4,500 ,,
Umtata	0.101 ,,	2,400 ,,
Kilrush	0.060 ,,	6,850 ,,
Daressalam	0.109 ,,	40 ,,
Kwai	0.060 ,,	5,280 ,,

Johannesburg is on the summit or ridge of a range which on each side falls away some 1500 feet, hence perhaps its small amplitude.

On the hypothesis, the time of highest and lowest mean pressures have to be reversed north of the mean thermal equator, so that the angle 270° ought to become 90°. To show that this is so, the table includes the following normal places,—Perim, Aden and India 30° N as well as some others. It is evident that in going from S to N we should meet with a neutral zone where the annual variation of pressure is almost or entirely lost. It would appear that on the W coast this

zone is about 10° N. Lat. We might expect that the single annual component would be replaced by a double variation due to the double passage of the Sun through the zenith,—this is not so, however, the double term becomes greater, but it is not larger than the first term except in Senegal.

The amplitude of the first term, so far as it is due to Sun-power should vary as some function of the height of the barometer and the difference between the highest and lowest temperatures, but in addition to these two factors, there is a third depending on the amount of aqueous vapour present. The temperature difference is greatest over continental areas whilst the amount of aqueous vapour has the most influence at marine stations.

The accompanying maps show the amplitude and phase of the first term over South Africa.

Mr. V. A. Löwinger has assisted me in the compilation and computations of this section.

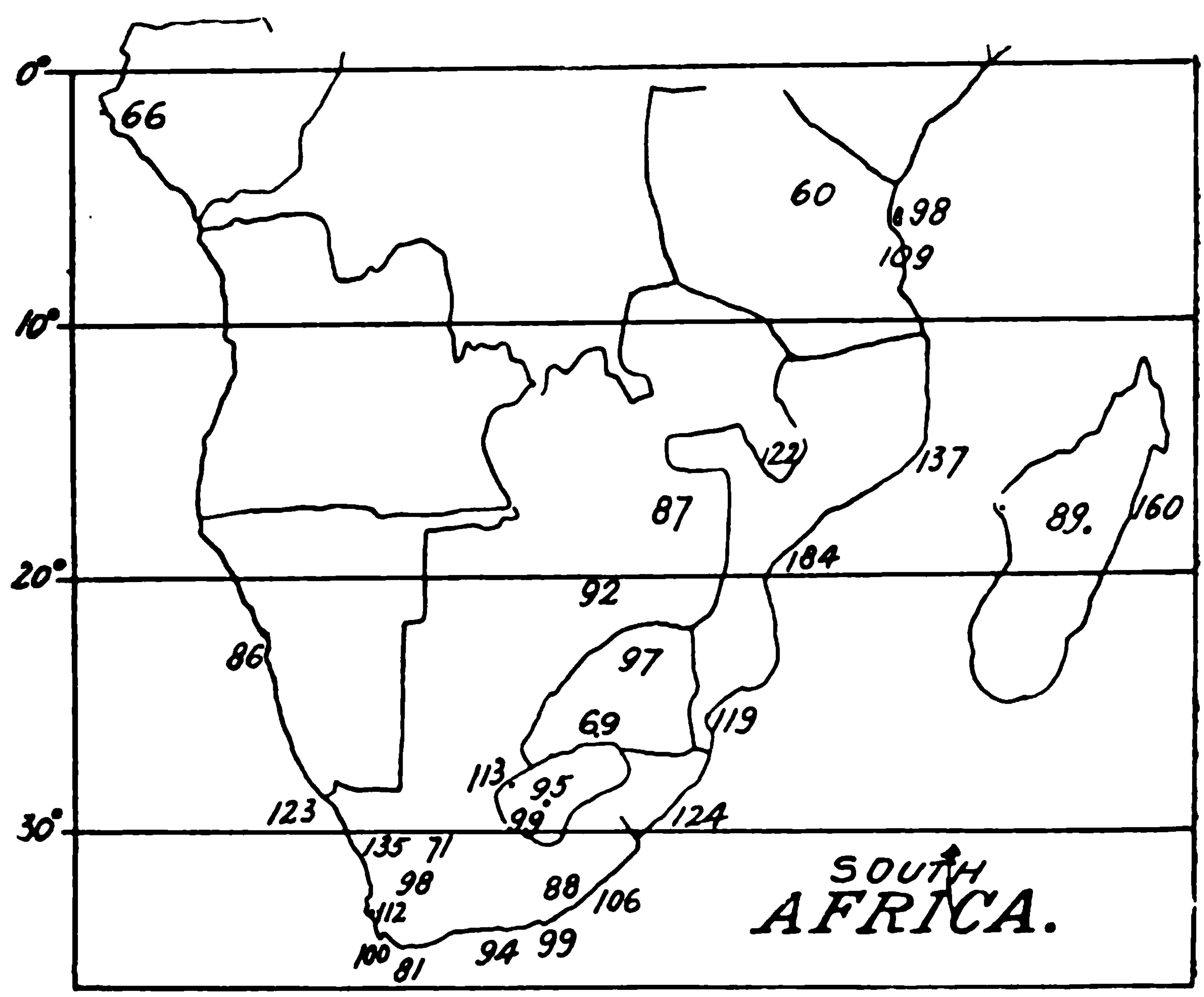


Fig. 2.—Amplitude of First Term.

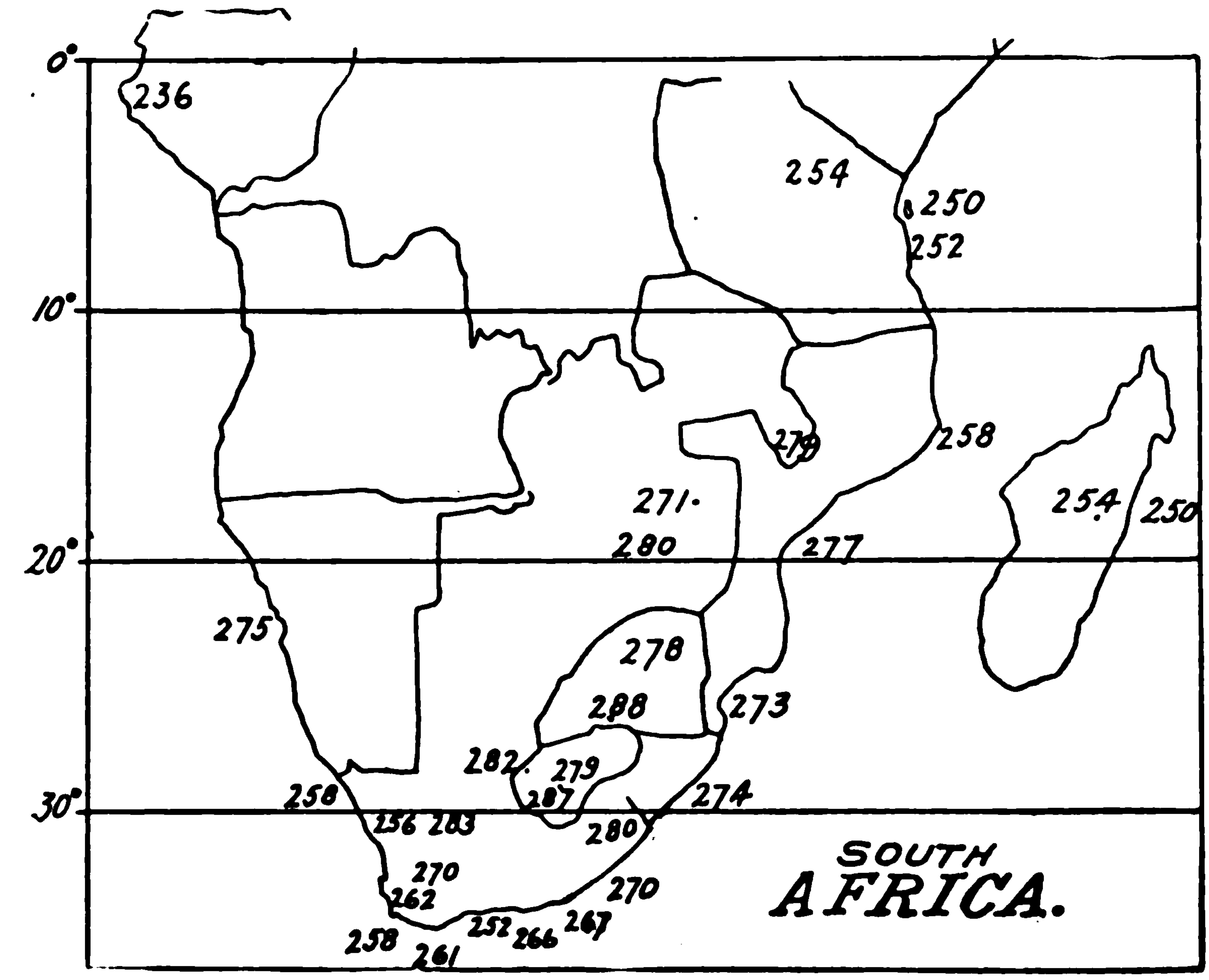


Fig. 3.—Phase of First Term.

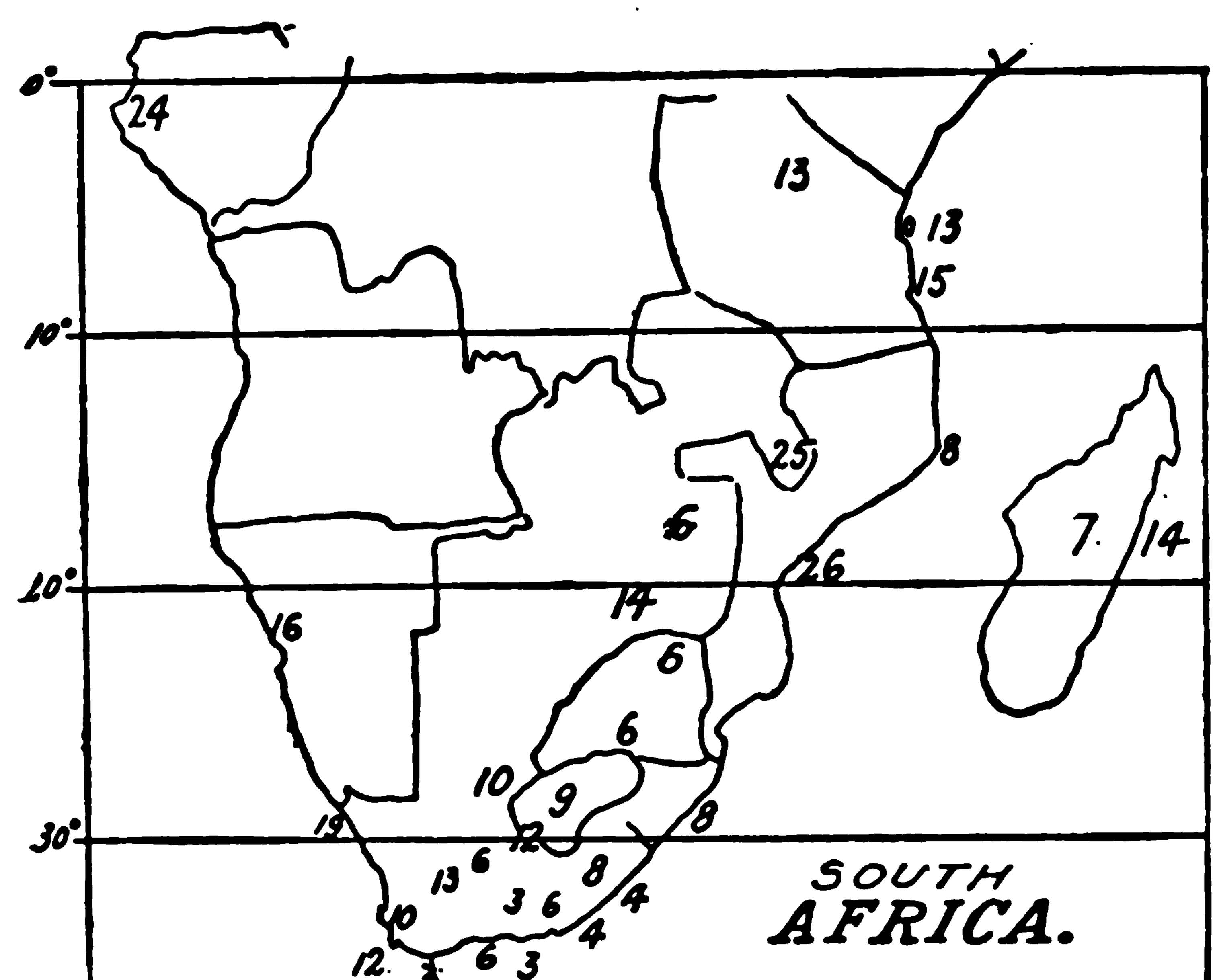


Fig. 4.—Amplitude of Second Term.

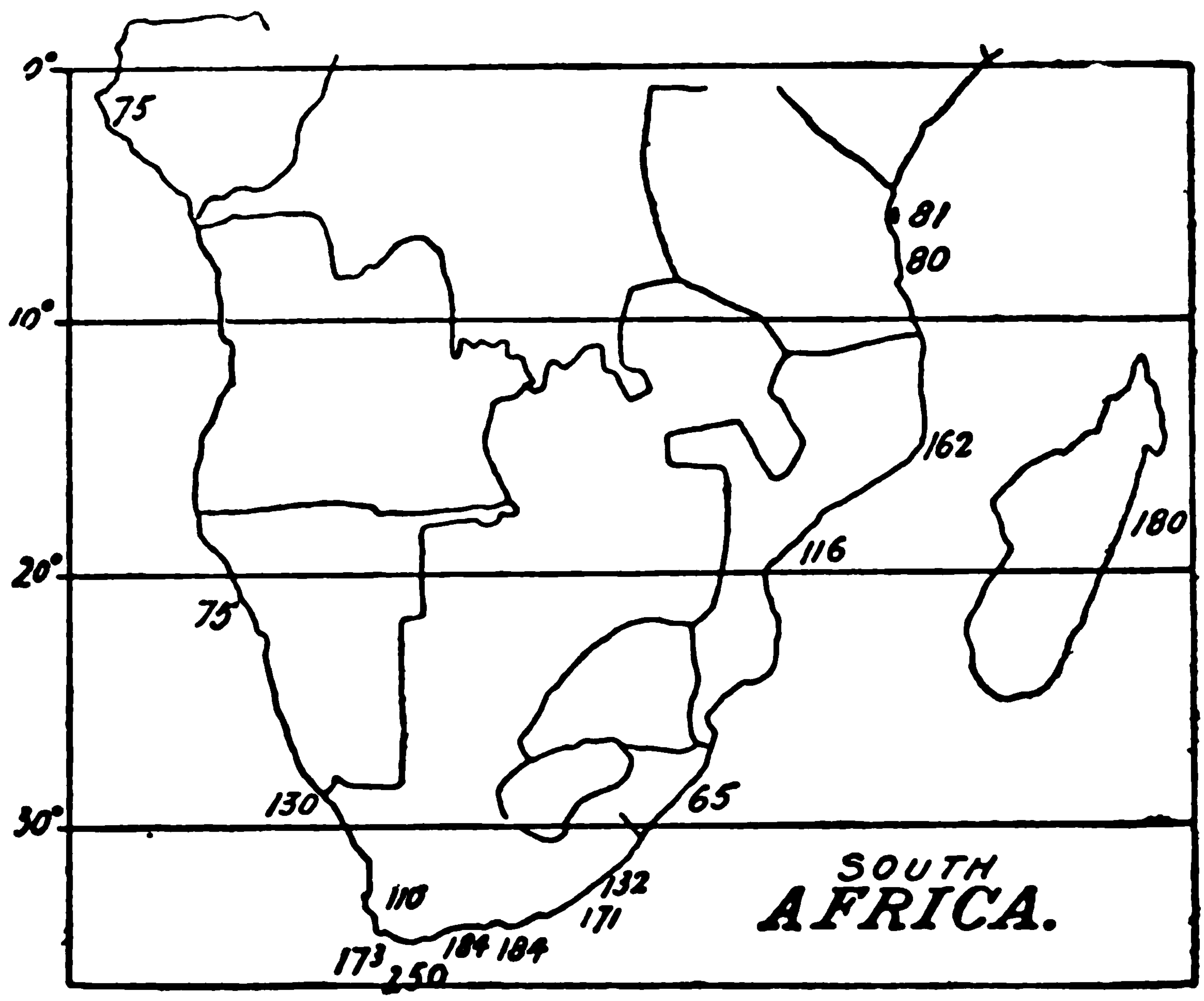


Fig. 5.—Phase of Second Term.

2. MOVEMENT OF ATMOSPHERIC DISTURBANCES ACROSS SOUTH AFRICA.

The annual variation of the barometer and the mean distribution of pressure from month to month control the more constant climatic features. A low mean barometer does not necessarily mean rain. It is true the season of the mean low barometer over the greater part of South Africa coincides with the Summer wet season, but this is not so over the region of the Cape Peninsula,—if so, the Summer with its low barometer should be wet and Winter with its high barometer dry, whereas, as a matter of fact, the Peninsula Summer is dry, the Winter wet. Rainfall is not associated with a mean low barometer but generally with a barometer below the mean of the season, fine weather with a barometer above the mean of the season. The steady march of the barometer is continually disturbed by the passage of depressions which bring disturbed weather. If we can find out the presence of a depression and in what direction it is moving, it becomes possible to predict the weather in its neighbourhood and path. If, on the contrary, there are no indications of any depression, it is safe to predict fine weather. Depressions usually travel from W to E and generally move away from the equator. If a depression is travelling

towards the E across any given place, the wind in advance of its centre blows from the equator, following its centre towards the equator. These and similar facts learnt from observation form the basis of weather-prediction.

Eight diagrams giving barometer curves made up from the morning observation at the Cape, Durban, and Johannesburg show the progressive movement of barometer disturbances from W to E, so that on the average, the changes take place 36 hours later at Durban and Johannesburg than they do at the Cape.

Diagram 1. (Upper half), 21st May 5th June, 1905

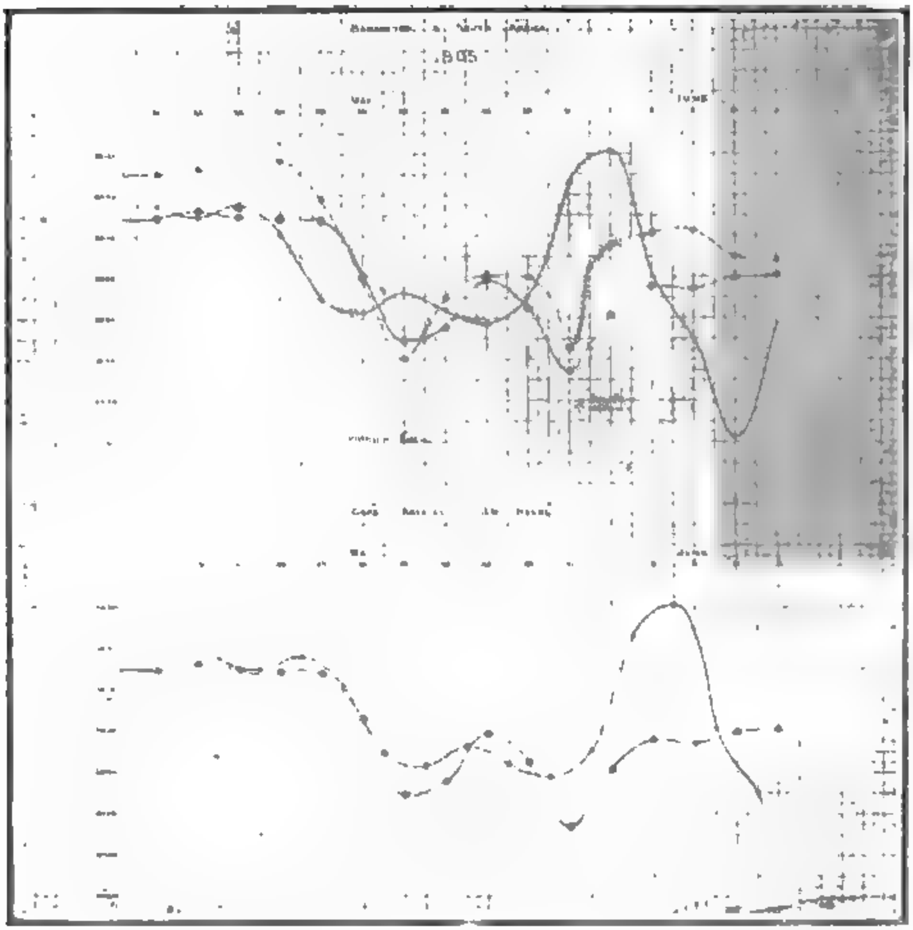


Diagram 2 -(Lower Half), 21st May 5th June, 1905.
(Cape Advanced 36 hours).

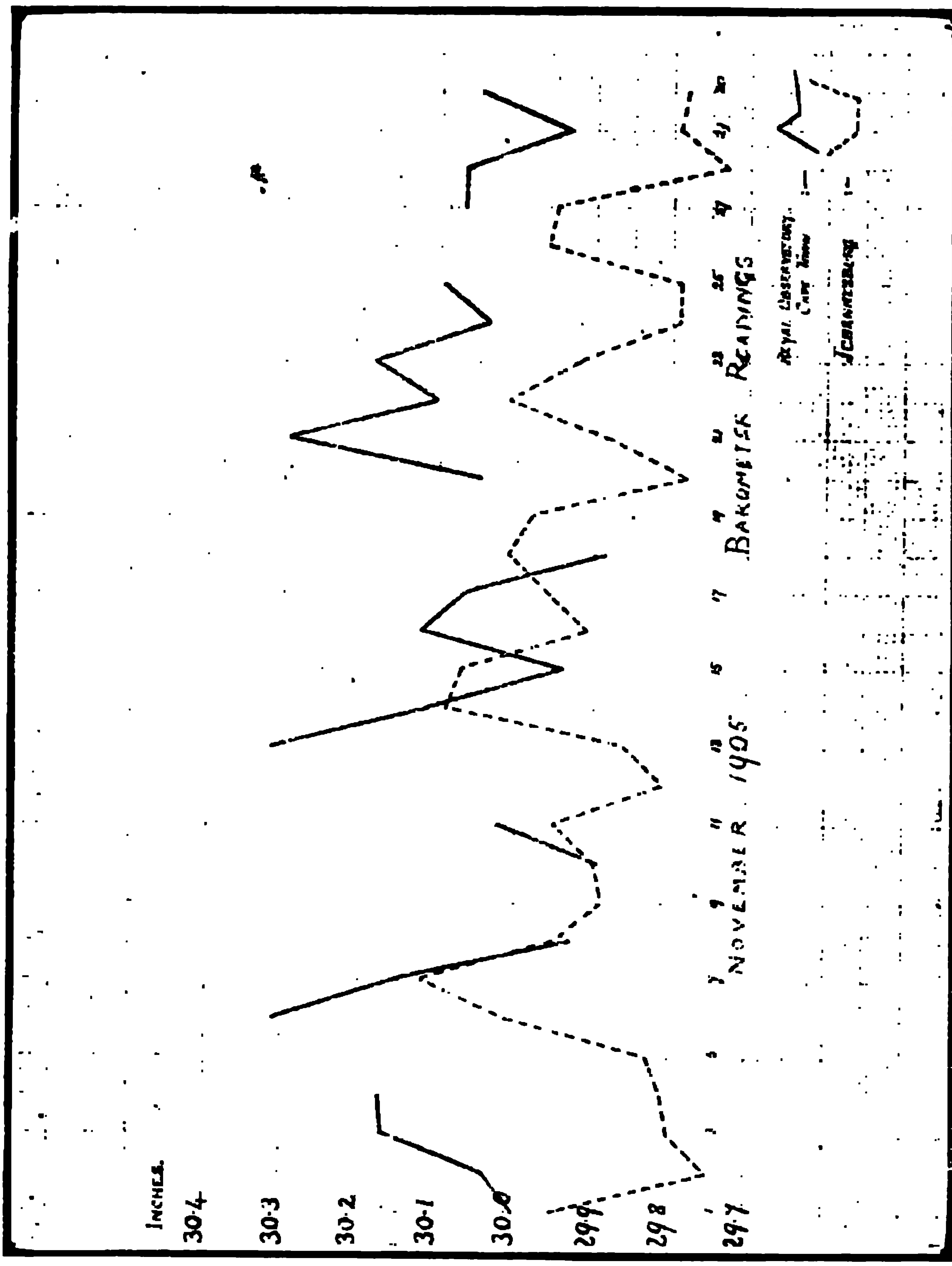


Diagram 3.—Barometer Readings, November, 1905.

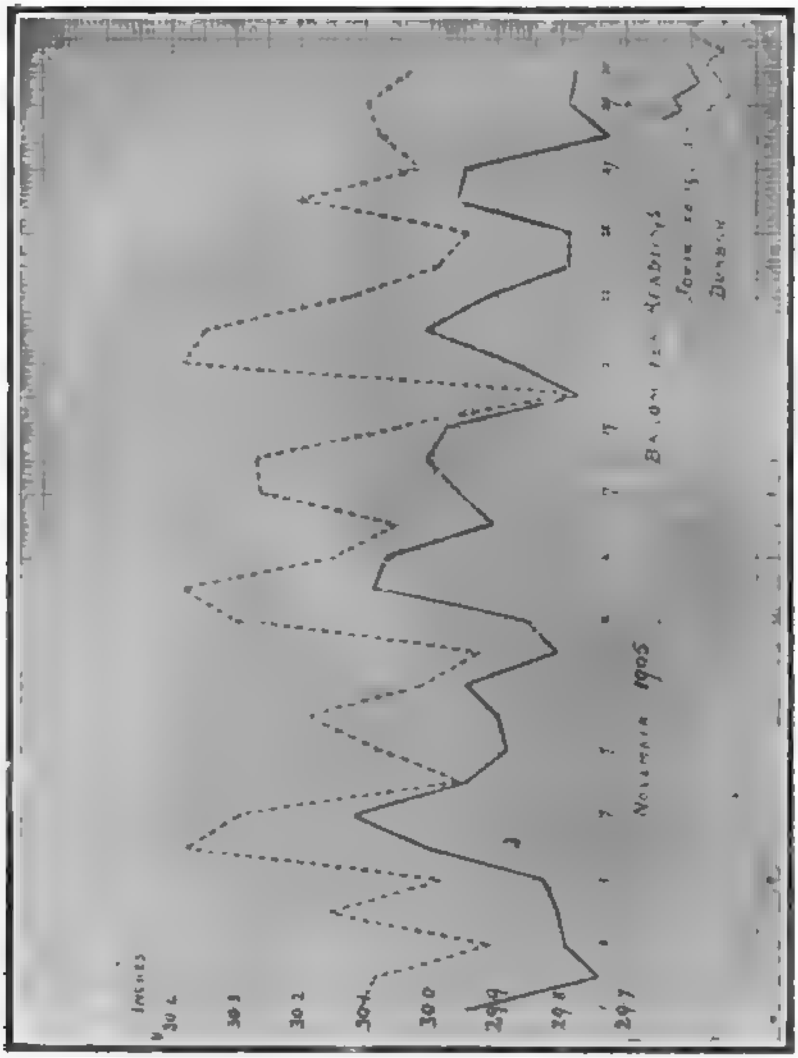


Diagram 4.—Barometer Readings, November, 1905.

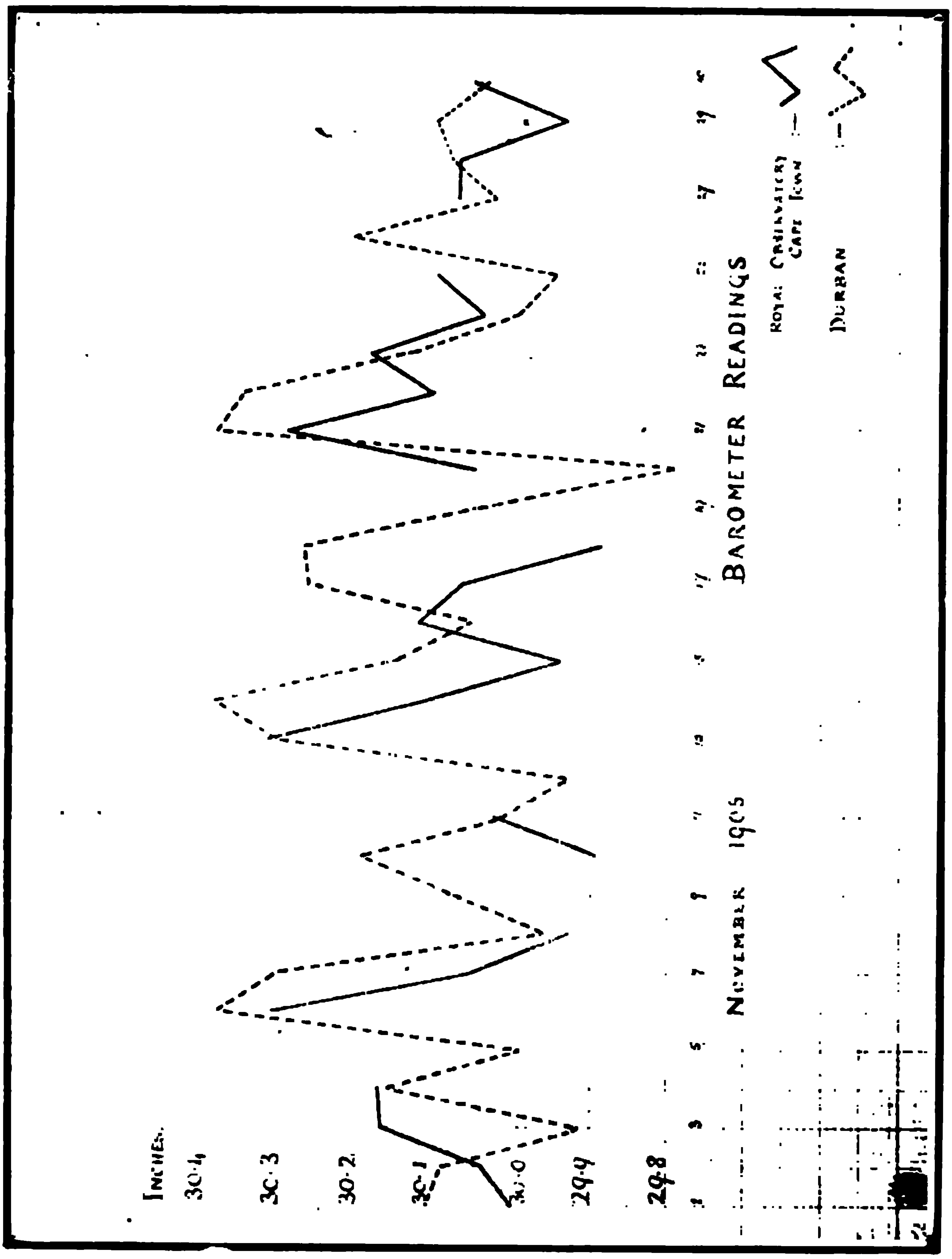


Diagram 5.—Barometer Readings, November, 1905.

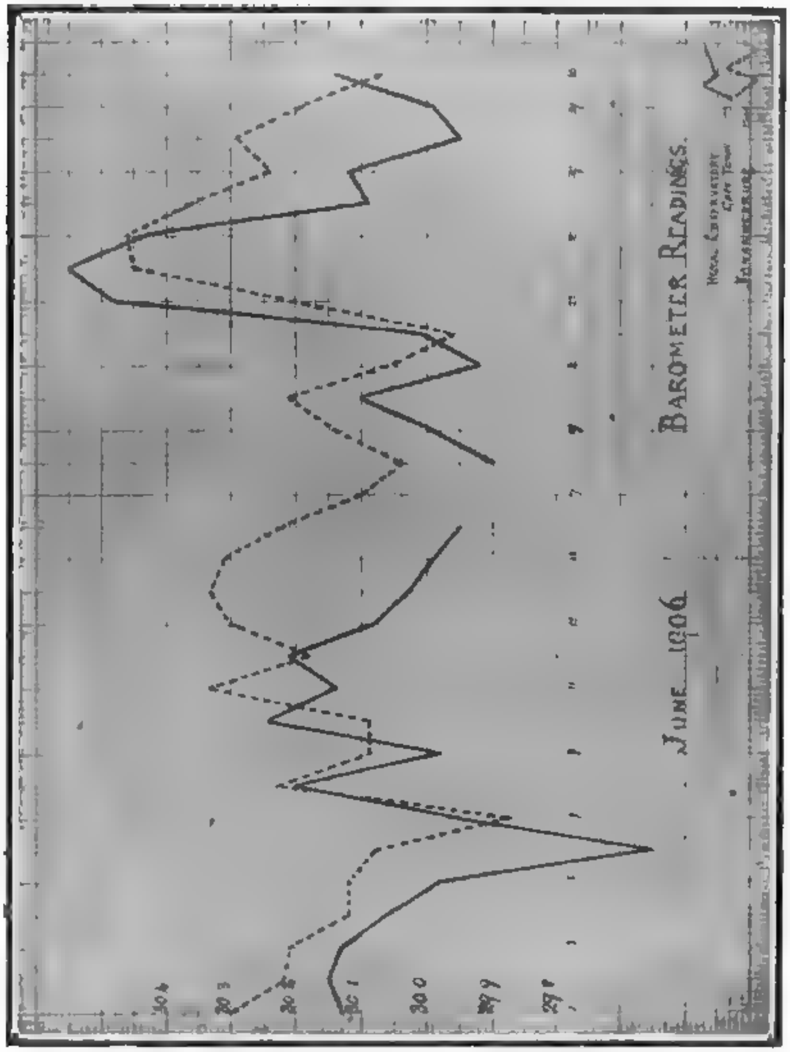


Diagram 6.—Barometer Readings, June, 1906.

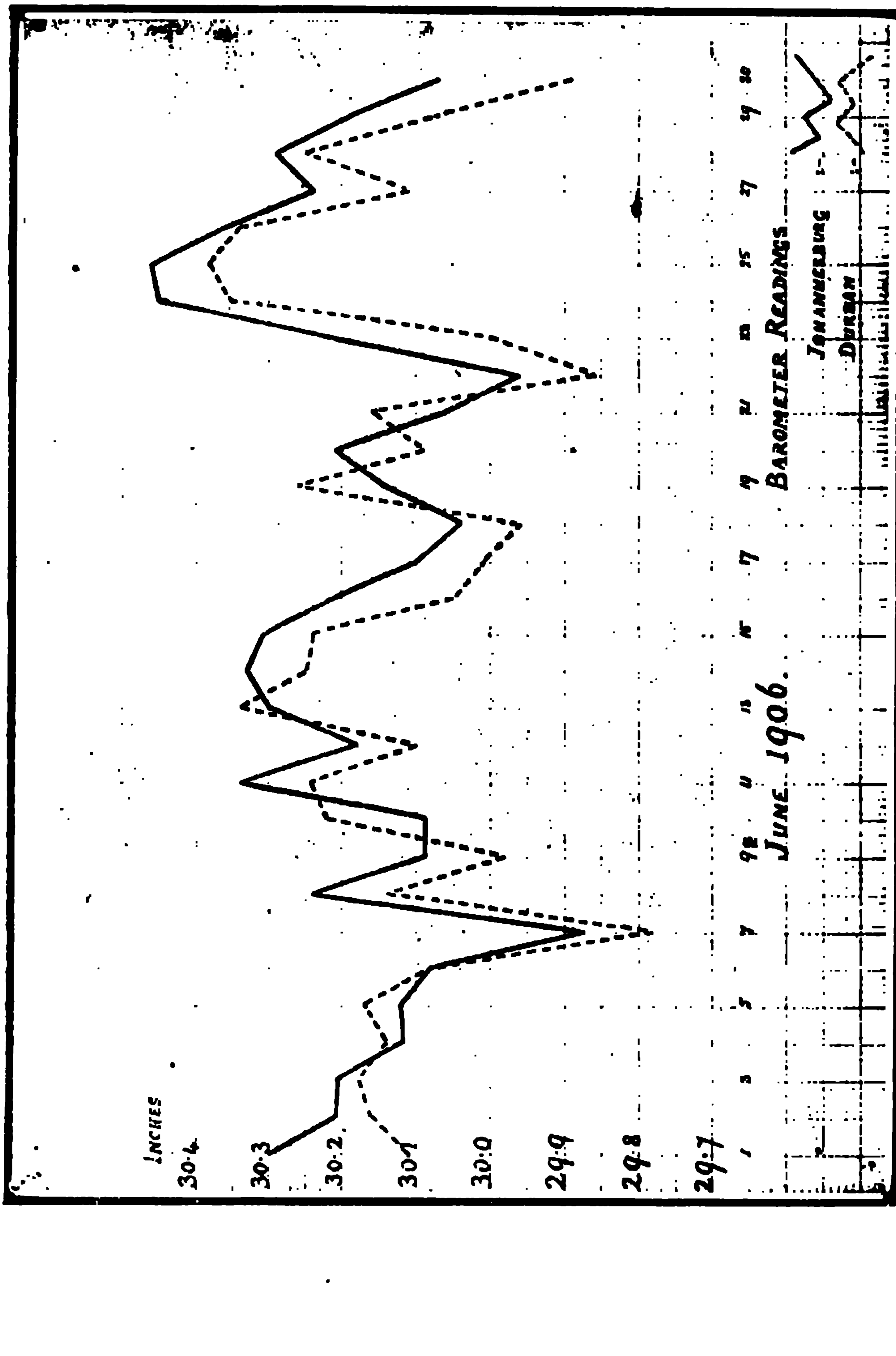


Diagram 7.—Barometer Readings, June, 1906.

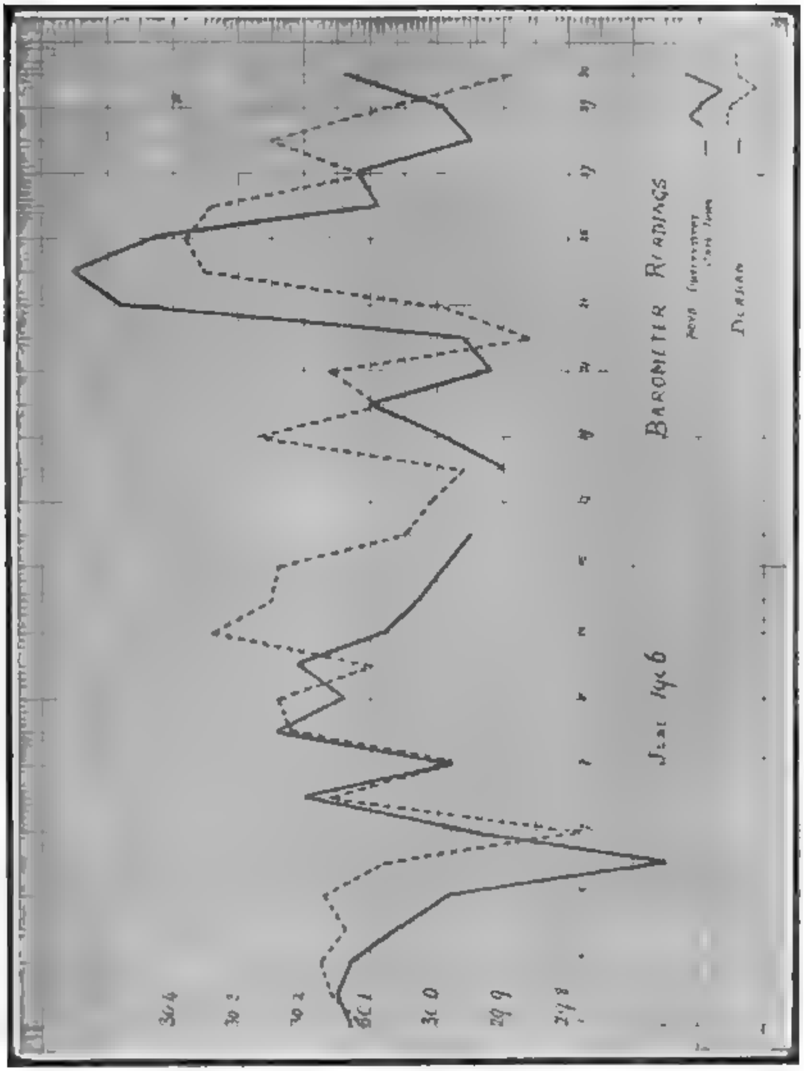
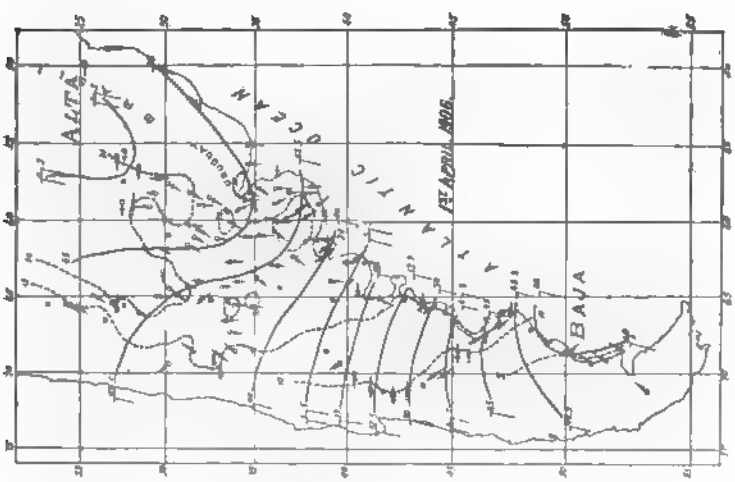
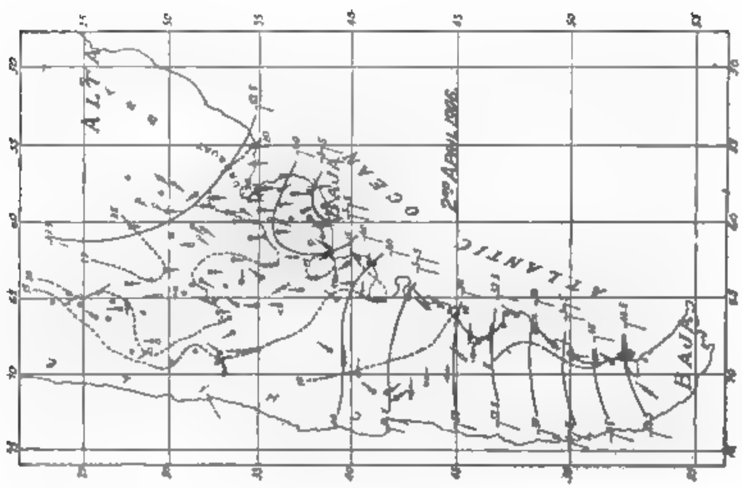


Diagram 8.—Barometer Readings, June, 1906.

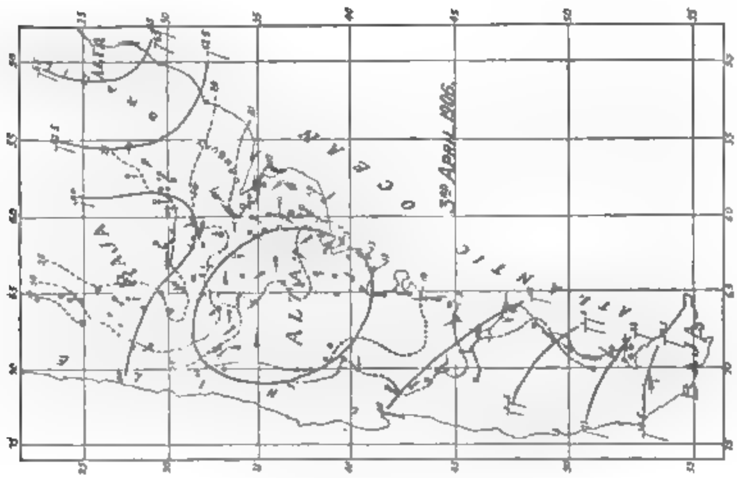
In these diagrams all pressures are reduced to sea-level, except that in the 1st and 2nd diagrams a constant reduction has been used for Johannesburg so as to bring the curve amongst the others. It will be noticed in the 1st diagram that there is a great similarity between the curves for Durban and Johannesburg, but that the curve for the Cape is displaced. In the 2nd diagram, the Cape curve is advanced 36 hours and compared with the Johannesburg curve. It is at once seen that the two curves now fit much better. The irregularities about the 31 May-1 June will be referred to further on. Collectively these diagrams show that the movements of the barometer at the Cape precede by 24 to 48 hours similar movements at Johannesburg and Durban. This is a fact of fundamental importance because, as just stated, it will permit us to forecast the weather. In Europe and North America the weather is governed by the advance, roughly from W to E, of closed areas of low barometer readings called cyclones, and analogy would predict that cyclones should also rule our weather in South Africa. Australian experience, however, warns us that this may not be so. Russell and Ellery both state that cyclones only play an insignificant part in Australian Meteorology, and that the weather there is governed by a procession, from W to E, of anticyclones or closed areas of high barometer readings, in between which are V shaped depressions which bring stormy weather. The excellent weather maps published by the Argentine Meteorological Office confirm the Australian experience. A continuous procession of cyclones is passing over S. America south of 40 S.Lat., whilst a continuous procession of anticyclones is found north of 35 N.Lat. This diagram made from 3 days' maps shows the usual routine.



Argentine, 1st April, 1906.



Argentine, 2nd April, 1906.



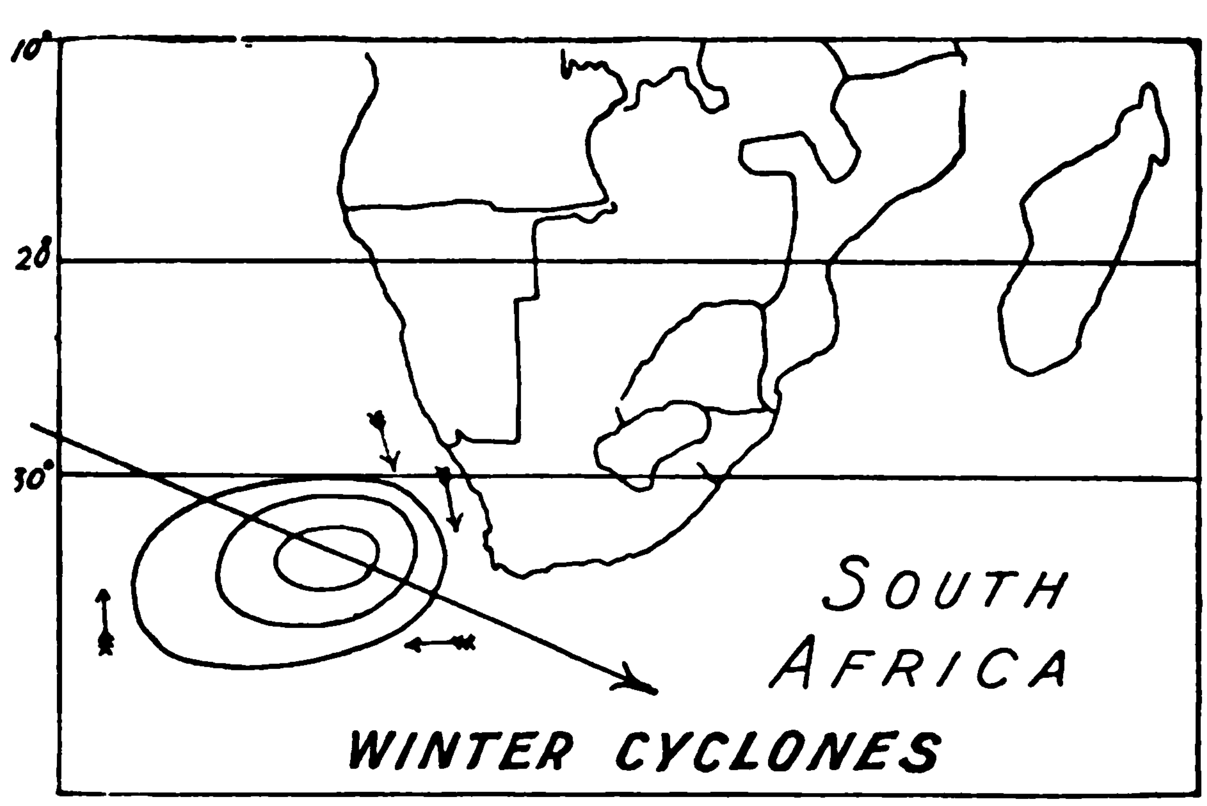
Argentine, 3rd April, 1906.

It is quite possible that cyclones north of 40° S. Lat. are broken up by the Andes, but against this we have the Australian experience. To answer these questions for South Africa, we require daily or semi-daily barometer readings from many stations all reduced to sea level, and these, except for coast stations, we have not got. But to make a start, we have, at the Johannesburg Observatory, assumed empirical reductions to sea-level for most of the stations in the Transvaal and

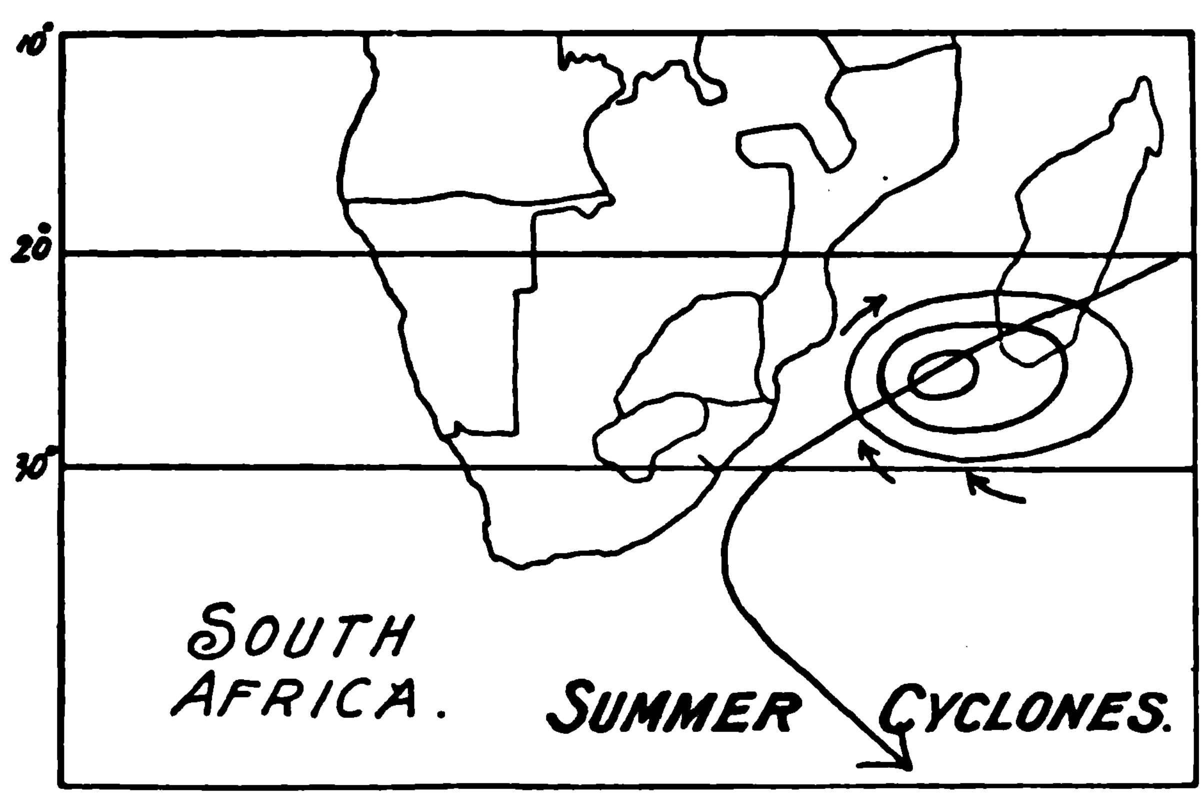
for Bloemfontein, Bulawayo and Salisbury, from which three inland stations we also receive daily wires. The empirical reduction is derived in this way :—Firstly, we assume the barometer reading and its altitude above sea-level are correct, and by means of the usual tables reduce the reading to sea-level. Then, by a comparison with neighbouring stations and isobars drawn having regard to the prevailing winds, we deduce a correction to our first sea-level reduction This is done from day to day and the constancy of the correction will be a justification for its regular adoption. We then attempt to draw isobars, but a terrible gap exists north of Cape Town and west of Christiana, so that allowances have to be made and some guesswork indulged in. Before coming to synoptic maps thus made let me explain by a few simply drawn diagrams a first theory of South African weather, not that I claim that it is correct, but it may serve to fix our attention, until it is replaced by some other. We have to account for the following facts :—

1. The Cape Peninsula has its wet season in winter.
2. The extreme south coast has rain at all seasons.
3. The rainfall at Durban is a summer rain, but it has two maxima, one before the other after the New Year.
4. The overlapping of these three periods of rainfall.

In accordance with Australian and South American experience we assume that a series of cyclones are traversing the southern ocean from W to E, in summer time far south of Africa, in winter time just skirting South Africa. In winter time there is a permanent anticyclone over South Africa, which in a general way wards off the cyclones so that they are forced to skirt the coast, and their tendency to move away from the equator is intensified. The diagram shows the ordinary course of a winter cyclone.



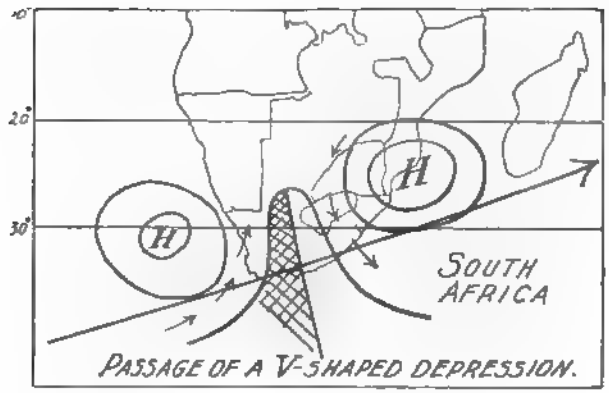
The long arrow shows the general movement of the cyclone, the short arrows, the direction of the wind. Such a cyclone brings low pressure, rain and NW gales to the Cape Peninsula, and passes to the south of Africa. If the cyclone is very large, it may extend from Port Nolloth to the Hex River and Port Elizabeth, bringing rain to the whole SW corner of Cape Colony. Passing now to the East Coast rains, we assume that these are due to cyclones in the Indian Ocean whose paths move in latitude with the Sun. In winter time these cyclones are too far north to interest us, but in summer time their path is just to the south of Africa. They come from the NE and turn to the SE as shown on the diagram.



These cyclones attain two periods of maximum intensity, the first about October or November on the Sun's southward progress, and again in February and March on its northward return. It is to these cyclones that the Transvaal owes its soaking east rains; unfortunately these rains die away very quickly as the distance from the coast increases, and very few ever reach to our western border. The southern sides of these cyclones bear the heaviest rains. A glance at these two diagrams will show that the extreme south coast is slightly under the influence of both cyclonic systems, and has therefore light rains at all seasons of the year.

Neither of these systems accounts for our inland rains. These are due to thunderstorms, and are accompanied by the usual barometric anomalies.

But as already pointed out by Mr. C. M. Stewart, of the Cape Commission, in the last volume of *Reports of the British Association*, South Africa owes most of its characteristic weather to the V shaped depressions which appear between the anticyclones. The diagram shows an ideal V shape.



The long arrow shows the path of the V. Its passage is marked by strong N winds with a rapidly falling barometer; the moment the trough of the V, marked by the line going NNW-SSE passes, the wind jumps to the south with a dust squall and lightning and rain soon follow, temperature falls very low and the barometer rises. Unfortunately for the Transvaal these V's seldom bring rain in winter time; we have the dust-storm, perhaps a few flakes of snow, and a stiff, cold gale from the S, which may last 48 hours.

It will be noticed that rain comes with a low and falling or nearly stationary barometer in a cyclone, but with a rising barometer in a V.

Thus the cyclonic rains of the Cape Peninsula in Winter show an unusually low pressure, whilst the occasional rains there in Summer show a pressure above the average. This is brought out clearly by the figures in Table 2 of the Cape Barometer tables in the 3rd section of this paper.

Referring back to the diagram showing the barometer curves about the period of the great storm at Durban, 31 May-1 June, we see that it shows all the characteristics of a V. For some days previous to the storm, the barometer was low over South Africa; this permitted the formation of a dangerous V, which, however, scarcely touched the Cape (on the 29th May); by the time the V had entered Natal and the Transvaal, pressure was rising rapidly at the Cape. The shading on the curves indicates rain, which, as usual, came with a rising barometer, the rainfall at Durban was terrific, at Johannesburg a few flakes of snow fell.

Such are my first ideas on our weather sequences. Without doubt, great modifications will be necessary. The theory of the eastern cyclones is distasteful to my preconceived ideas, but I accept it and other theories for the time being.

For the purposes of weather prediction in the Transvaal, our material, though insufficient, is not too bad. We cannot be sure of depressions approaching the Colony from the NE, as we receive no telegraphic reports from that direction. We should also like telegraphic reports from a station considerably to the N. of Cape Town, such as Swakopmund in German West Africa, and another in the N of the interior of Cape Colony, such as Prieska. If our friends of the Cape should decide to issue forecasts, they have the means at hand for their Eastern Province, but for the Western Province an ocean station is required; fortunately one exists in St. Helena, and I have no doubt it could be easily arranged to get a daily weather cablegram from that island.

Thanks to the co-operation of the other meterological services of South Africa, the numerous voluntary observers in the Transvaal, and the ready co-operation of the Telegraph Authorities, we are now able to make a daily synoptic weather map covering a considerable part of South Africa. I show six of these maps which have been prepared by Mr H. E. Wood, who has been lately appointed to the Transvaal Meteorological Department, and who has had training in forecasting under Dr. W. N. Shaw, of the Meteorological Office, London. The first map (Thursday, June 21), shows an anticyclone over the O.R.C. with its accompanying light winds. The low barometer and N.W. winds with rain over the Cape Peninsula show the approach of a depression. The next map (Friday, 22 June) shows that the depression has swept along the south coast, bringing considerable rains, but that it had not yet affected the Transvaal, where temperatures were still high and N winds prevailed. The change came on Friday night. The map for Saturday, 23 June, shows the influence of the depression which apparently passed over South Africa in the form of a V. A southerly gale is reported from nearly every station, but it is still calm at Bulawayo. Temperatures are very low, and pressure along the W coast is rising rapidly. The coast rainfall, if any, which would be measured on Sunday morning, is omitted, as we do not receive Sunday wires from the Cape Meteorological Commission, the only coast stations reporting being the Observatories at the Cape and Durban. The Sunday map (24 June) shows a high pressure over the Cape, the influence of the V is now felt at Bulawayo, where a stiff SE gale is blowing. Bitterly cold S winds still prevail over the Transvaal, but the rising barometer indicates a lessening wind and warmer weather. The map for Monday, 25th June, shows that the region of high pressure has moved up to the O.R.C. and Transvaal, whilst over the rest of South Africa pressures are fairly high and remarkably even. The winds indicate the existence of small local anomalies in the SW, but from lack of data, isobars cannot be drawn. The last map (Tuesday, 26th June) shows that the anticyclone maintains its position over the High Veldt and Natal, whilst a low pressure is passing considerably to the south of the south coast. The indications for a forecast with such a map point to continued fine weather, light winds, sunny days, and cold nights.

The remarks already made indicate how these maps are used for our daily forecasts. By 3.30 p.m. every day (excepting Sundays) a forecast for the ensuing 24 hours is now exhibited at every telegraph office in the Transvaal. This service started on the 1st July, 1906. It is pleasant to make this announcement here, because, as you will remember, the Transvaal Meteorological Department is a child of the Association.

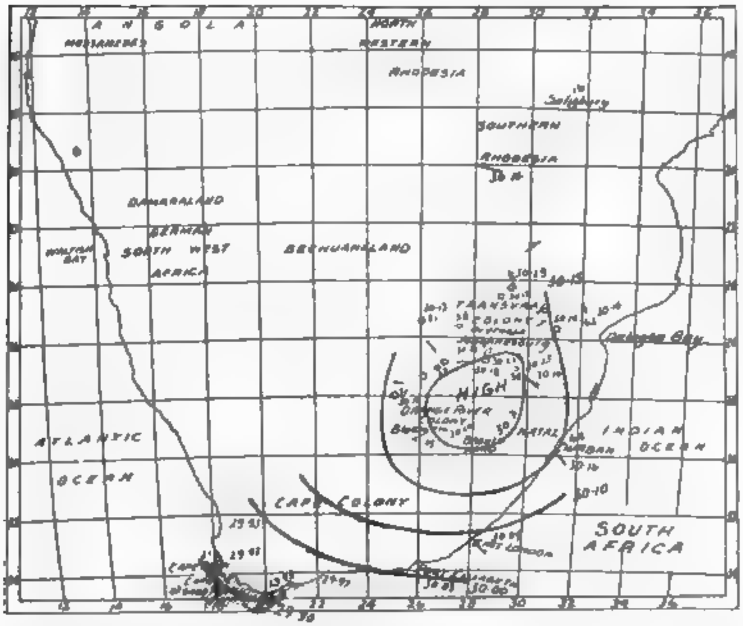
I consider that a very great obligation rests on the shoulders of Government meteorologists in South Africa. The lot of the farmer in this semi-arid country is not to be envied. It therefore behoves us to do our utmost to assist him in his work by providing him with the most accurate forecasts that science can furnish. It seems to me that it will soon be in our power to do so with an accuracy unknown in Europe or America, and if I am right in this opinion, let us consider the effect. It is safe to say that it will improve the farmers' chances of success by 25 %.

I look forward to and will welcome similar forecasts from the neighbouring services, and hope that it will not be considered out of place if I make an earnest appeal to the Cape Meteorological Commission to take a step forward and bring itself into line. We value the 30 volumes of observation the Commission has already published, but hope that the future will bring forth something more than these weighty and somewhat crystallized compilations, each one of which, by the very fact of those that have preceded it, is of less value to meteorological science.

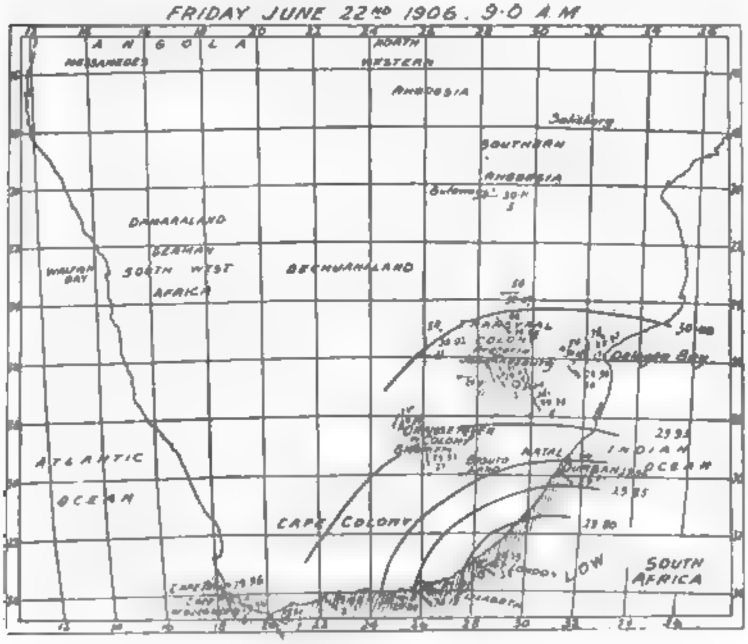
Last week, I had the pleasure of a visit from Major Chaves, the Director of the Azores Meteorological Service, who is visiting the various colonies of South Africa to study the conditions of the meteorological services there, and especially at the request of Mr. Hugh de Lacerda, Captain of the Port at Lourenço Marques, to report on the suitability of Delagoa Bay as a site for a first-class meteorological observatory, which it has been proposed should be erected there. Already east of 24° E.Long., there are several good meteorological observatories, viz., Durban, Bulawayo, Kenilworth (Kimberley) and Johannesburg, whilst on the west there is not one.

A first-class meteorological observatory at the Cape, besides being of great value in forecasting for Cape Colony, will also be of great value to all the other Colonies of South Africa. I venture to hope that this Association, which was instrumental in starting the Transvaal Weather Service, will urge the Cape Government to start such an observatory near the Cape Peninsula.

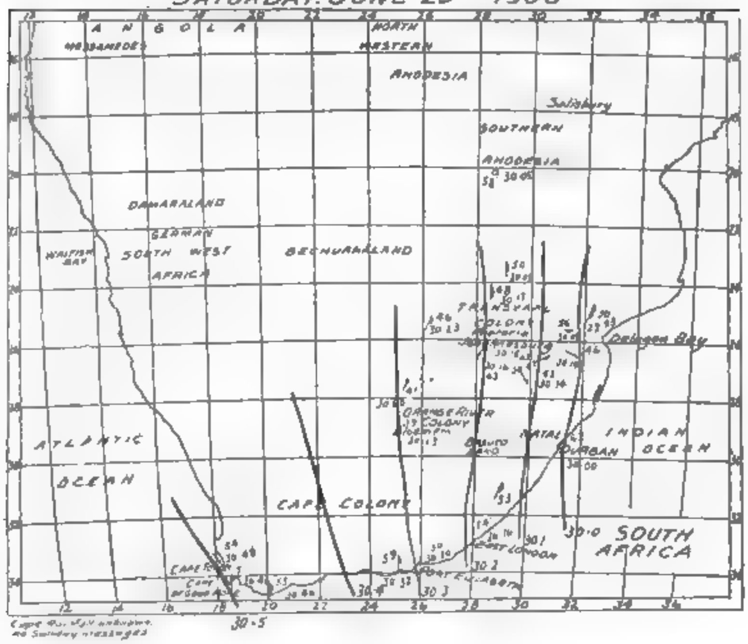
THURSDAY, JUNE 21ST 1906.



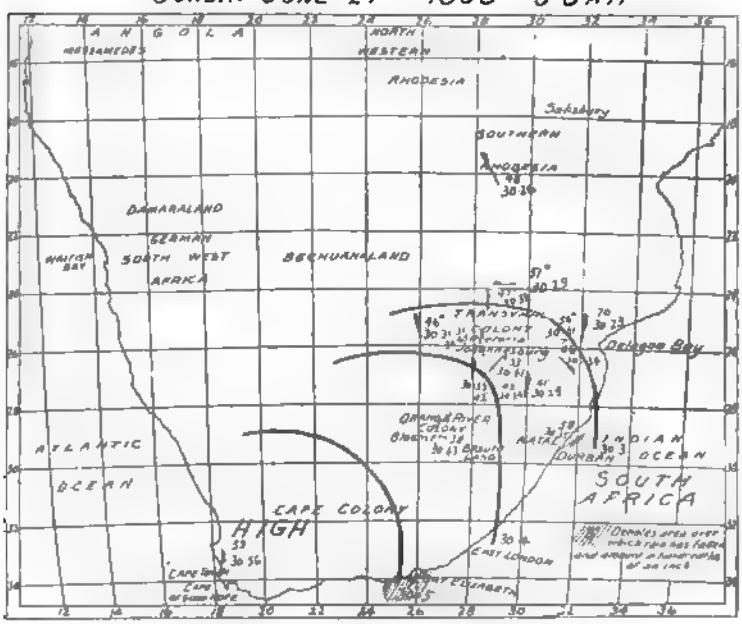
FRIDAY JUNE 22ND 1906. 9·0 A.M



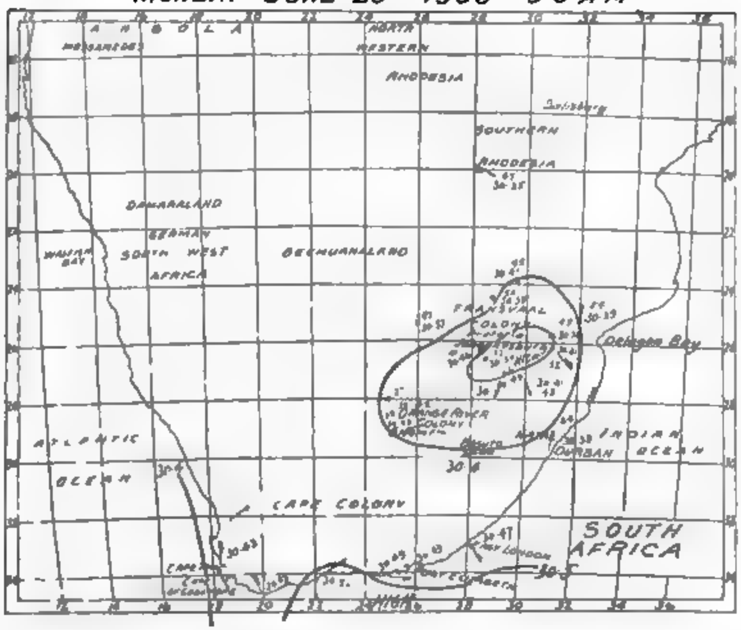
SATURDAY. JUNE 23RD 1906



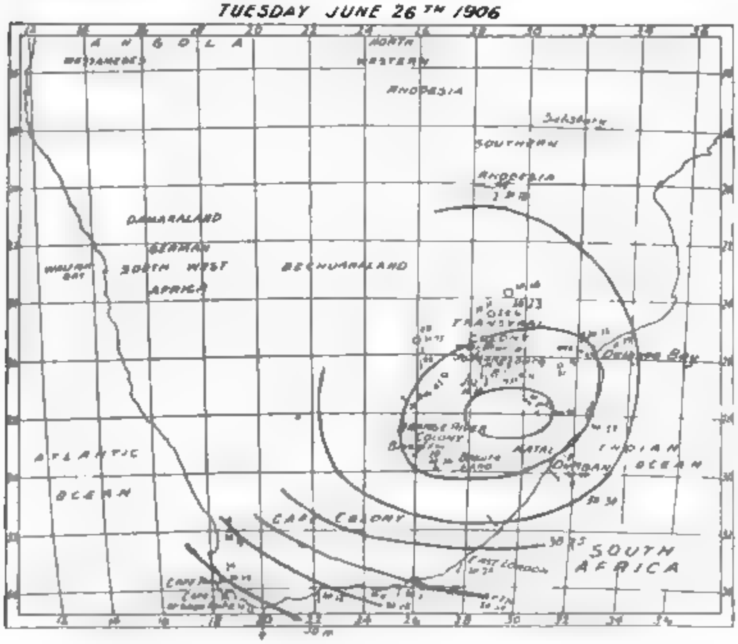
SUNDAY JUNE 24TH 1906 9 O A M



MONDAY JUNE 25TH 1906 9 0 A M



TUESDAY JUNE 26TH 1906



3—BAROMETER OBSERVATIONS.

(a) ROYAL OBSERVATORY, CAPE OF GOOD HOPE, 1841-1905.

Readings of the Barometer at the Cape Observatory are available (with the exception of a few slight interruptions in the earlier years) since April, 1841.

From 1841 to 1846, the observations were made under the general direction of Sabine, and since that date, under the direction of H.M. Astronomers at the Cape. The observations made from 1841 to 1846 have been published at length (Observations made at the Mag. and Met. Observatory at the Cape of Good Hope. Vol. II., Meterological Observations. London, undated). These, with the observations to 1870, were discussed and published by the late E. J. Stone (Results of Met. Observations, Cape Town, 1871). Since 1875, the monthly means have been published in the annual reports of the Cape Meteorological Commission.

There were several reasons which made it desirable to re-discuss the whole series from 1841 to date. The volumes containing the results to 1870 are not common; the observations 1871-74 have never been printed; and several of the Cape Meteorological Commission Reports are unobtainable. Then it is necessary to reduce the whole series in a homogeneous manner. This involves the reduction to the mean of the day, as it is obvious, for example, that the means of observations taken at 9 a.m. will be quite different from those taken to 1 p.m. and so on.

From 1841 to 1846, hourly or two hourly observations were taken. From 1846 to 1870, five observations a day were taken—the reduction to mean of day for this series, only amounts to 0.002in. during the month of October,—this reduction has only been applied between 1847 and 1850. From 1871 onwards, the hours of observation have varied as follows :—

1871-72	At 3, 9, 15 and 21 hours, mean local time.
1873	At 9, 15 and 21 hours.
1874-1878 Jan. 11	At 0, 6, 12, and 18 hours.
1878 Jan. 12-Dec. 31	At 0, 6, 13½, and 18 hours.
1879-1880	At 6, 13½,, and 18 hours.
1881-1883	At 6, 13⅓, and 22 hours.
1884-1889	At 8 and 13⅓ hours.
1890	At 8, 1⅓, and 20 hours.
1891-1892 Feb. 7	At 8, 12, and 20 hours.
1892 Feb. 8, 1902	At 8*, 12, and 20* hours.

To reduce to mean of day, we have at our service, Stone's Table XIII. in the volume already quoted. This table has, however, not been used. Inspection of it indicates the presence of anomalies in the observation of 1841-1846 on which it is based. The exposure of

* Mean Time of 22½° E.

the barometer between those years was essentially different from that of latter years. A slight difference of exposure in a place so subject to violent southerly winds, as is the Cape Observatory, would modify the diurnal curve. (For some remarks on the buildings and exposures, see Gill, Journal Royal Meteorological Society. Vol. VIII., p. 238.) It has therefore been attempted to derive the reductions to mean of day from the series of observations, 1871 to 1905 themselves. Stone's figures for each month were first plotted, and the deviations of the later series were inserted, a freehand curve was then drawn, and the reductions to mean of day were taken from this curve. Two solutions were essayed and the mean adopted. Table 1 shows the whole scheme.

One example will suffice to show how the observations have been reduced to the mean of day. We take those for January, 1891 :—

	A.	B.	C.
	ins.	ins.	ins.
8 hours	29.903	29.890	29.886
Noon	.889	.880	.884
20 hours	.887	.877	.884
Means	29.893	29.882	29.885

The mean of A represents the unreduced mean, that of B is derived by using Stone's reductions, that of C by using the mean of the solutions I_1 and I_2. Applying +0.009ins., we have the figure given in the table of mean monthly readings. This example proves that it is impossible to deduce the annual or even the monthly changes in pressure unless there is an accurate reduction to "mean of day."

It is believed that the same barometer has been in use since 1841. It is Newman's No. 53, the interior diameter of the tube is 0.51ins. The scale is attached to an ivory point, which is adjusted to the surface of the mercury at each observation. Although the barometer has remained unchanged, the index errors applied, have varied from time to time.

During 1841-46, the readings published by Sabine were reduced to 32° F. No statement about capillarity or index error is available, but it is probable that they have been applied. It is the custom at the Cape Observatory to include the correction for capillarity + 0.003) in the temperature reduction, and Stone has evidently considered that Sabine did so as well.

If the Cape barometer is corrected to 32° F., and for capillarity, we assume it still requires the following reductions :—

To Sea-level 37 feet	+ 0.042
To Standard Gravity 45° Lat.	−0.030
Provisional Index error	−0.013
Total	−0.001

Therefore if we use Stone's figures for 1841-70, we must apply −0.038 to them.

From 1871-80, capillarity alone, and from 1881 to date capillarity and −0.013 index error were applied. In a tabular form these reductions are shown as follows:—

Reduction previously used.		Reduction to Prov. Standard.
	in.	in.
1841-46	+0.037	−0.038
1847-70	+0.040	−0.041
1871-80	+0·003	−0.004
1881-date	−0.010	+0·009

The barometer at the Cape, at least during the winter months, is lower during heavy rains. Table 2, based on the observations 1841-1870, shows the three heaviest and three lightest monthly rainfalls for each month with the corresponding barometer means.

The tables which follow require no further explanation. The cost of compiling the Cape monthly means has been met by a grant from the Association.

P.S.—Mr. J. Power, of the Royal Observatory, has been good enough to read the foregoing. He considers that from 1847 to date my provisional standard should be corrected by +0.003in. Since the above was put in type I have come across a paper by Maclear giving the monthly means for 1842-1855 (*Board of Trade Meteor. Papers*, No. 1, 1856). An inspection of Maclear's figures shows that Mr. Power is right, and that from 1847 (inclusive) onwards 0.003in. should be added to all the printed figures in Tables 2-3-4.

TABLE I.

BAROMETER, ROYAL OBSERVATORY, CAPE OF GOOD HOPE. REDUCTION TO MEAN OF DAY.

Unit = 0·001 inches.

Hour.	January.			February.			March.			April.			May.			June.		
	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2
Midnight	- 9	- 8,	- 6	- 8	- 7,	- 8	- 4	- 4,	- 3	- 3	- 2,	- 3	- 4	- 6,	- 4	- 8	- 5,	- 7
3 ...	+24	+20,	+19	+19	+18,	+16	+12	+17,	+17	+18	+14,	+20	+ 7	+11,	+ 8	+10	+14,	+12
6 ...	3.	- 1,	- 2	3	- 1,	5	1	- 1,	- 2	6	- 2,	0	4	- 2,	2	12	0,	- 1
8* ...	-12	16,	15	-14	18,	-17	-18	19,	21	-14	21,	-21	-16	20,	-15	-11	-18,	20
8 ...	13	18.	16	16	20,	21	20	21,	23	18	23,	23	19	22,	18	13	20,	22
9 ...	14	19,	19	20	23,	28	25	26,	28	26	27,	26	29	26,	26	25	30,	27
Noon* ...	10	8,	9	11	13,	10	13	12,	14	12	9,	11	11	4,	2	12	8,	5
" ...	9	6,	4	9	9,	8	10	10,	11	9	6,	7	6	0,	+ 2	6	2,	0
13½ ...	0	+ 2,	+ 3	+ 2	+ 1,	+ 3	+ 8	+ 4,	+ 6	+10	+10,	+10	+20	+17,	22	+15	+16,	+18
13½ ...	0	4,	5	4	4,	5	10	6,	8	12	12,	11	22	18,	24	17	18,	19
15 ...	+21	13,	15	16	15,	21	23	18,	21	19	22,	20	28	28,	29	23	26,	28
18 ...	11	15,	16	16	17,	15	15	14,	15	9	10,	6	9	8,	8	4	7,	8
20* ...	- 8	- 1,	- 1	- 4	1,	- 1	- 1	0,	- 7	- 4	- 3,	- 8	- 4	- 7,	- 9	- 8	-11,	- 7
20 ...	10	3,	3	7	- 1,	3	4	- 3,	8	7	5,	9	6	9,	10	9	13,	9
21 ...	18	13,	10	16	11,	10	10	9,	11	9	9,	10	8	12,	13	11	14,	13
22 ...	21	18,	12	17	16,	16	8	12,	12	12	11,	13	10	13,	12	14	13,	14

* Mean time of 22½° E.

TABLE I.—*Continued.*

BAROMETER, ROYAL OBSERVATORY, CAPE OF GOOD HOPE. REDUCTION TO MEAN OF DAY.

Unit = 0·001 inches.

Hour.	July.			August.			September.			October.			November.			December.		
	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2	S	I_1	I_2
Midnight	− 2	− 5,	− 2	− 5	− 3,	− 3	− 1	− 2,	− 2	− 8	− 2,	− 3	− 6	− 3,	− 2	− 9	− 4,	− 6
3 ...	+ 8	+ 14,	+ 11	+ 12	+ 16,	+ 13	+ 18	+ 17,	+ 18	+ 20	+ 16,	+ 15	+ 20	+ 16,	+ 16	+ 20	+ 22,	+ 18
6 ...	4	2,	4	4	3,	2	− 2	3,	3	− 4	1,	− 3	− 2	1,	0	− 1	− 2,	− 1
8* ...	− 14	− 20,	− 18	− 16	− 18,	− 19	20	− 16,	− 16	17	− 14,	19	14	− 12,	− 14	15	15,	13
8 ...	16	22,	22	19	20,	20	22	18,	18	18	16,	20	16	13,	15	16	16,	14
9 ...	27	29,	32	26	28,	25	27	26,	23	22	20,	22	16	15,	16	15	16,	14
Noon* ...	14	10,	12	10	14,	13	12	13,	10	5	9,	6	5	7,	7	9	8,	5
,, ...	8	6,	9	6	10,	9	10	10,	7	3	6,	4	3	5,	5	7	6,	3
$13\frac{1}{3}$ ...	+ 13	+ 13,	+ 12	+ 13	+ 9,	+ 13	+ 12	+ 8,	+ 19	+ 8	+ 9,	+ 12	+ 7	+ 7,	+ 15	+ 3	+ 2,	+ 4
$13\frac{1}{2}$ ...	15	13,	13	16	9,	16	13	9,	21	10	11,	14	9	9,	16	5	3,	6
15 ...	23	26,	22	24	24,	23	24	23,	26	24	23,	25	19	20,	26	17	11,	15
18 ...	8	9,	8	7	10,	9	10	8,	11	9	7,	11	8	9,	8	14	11,	11
20* ...	− 2	− 6,	− 9	− 6	− 6,	− 8	− 6	− 9,	− 7	− 12	− 12,	− 11	− 12	− 12,	− 13	− 6	− 3,	− 7
20 ...	4	7,	10	8	8,	10	9	10,	9	16	15,	14	14	15,	14	8	5,	10
21 ...	7	11,	12	12	12,	12	12	14,	12	19	19,	18	20	21,	21	18	17,	18
22 ...	8	12,	11	12	12,	12	10	14,	10	15	18,	18	19	21,	21	23	23,	21

* Mean time of $22\frac{1}{2}°$ E.

TABLE 2.

Showing the three heaviest and lightest monthly rainfalls 1841-1870 with the corresponding Barometer means.

Jan.			Feb.			Mar.		
	ins.	ins.		ins.	ins.		ins.	ins.
1845	3.18	29.951	1866	3.10	29.876	1863	2.91	29.920
46	2.41	.948	48	1.92	.875	53	2.13	.962
50	2.07	.898	44	1.89	.926	52	1.65	.938
1848	0.05	29.870	1869	0.06	29.942	1870	0.16	29.914
66	0.03	.921	51	0.04	.943	51	0.15	.994
43	0.01	.946	64	0.01	.887	57	0.13	.955

April			May			June		
	ins.	ins.		ins.	ins.		ins.	ins.
1850	4.38	29.969	1846	8.96	30.063	1862	10.78	29.952
47	3.36	30.009	69	8.06	.029	69	9.52	20.061
44	3.12	29.989	59	6.92	29.969	61	7.61	.091
1859	0.78	30.052	1866	0.76	30.108	1846	2.08	30.124
49	0.58	.015	58	0.75	.120	52	1.71	.167
56	0.44	.023	44	0.34	.124	65	0.93	.208

July			August			Sept.		
	ins.	ins.		ins.	ins.		ins.	ins.
1870	6.74	30.136	1847	6.03	30.139	1860	5.02	30.048
59	6.52	.155	58	5.61	.050	55	4.88	.098
62	6.28	.066	55	5.25	.074	59	3.22	.038
1847	1.77	30.130	1860	0.92	30.098	1869	1.18	30.074
42	1.71	.198	68	0.69	.116	68	0.90	.071
41	1.23	.208	51	0.59	.190	65	0.65	.062

Oct.			Nov.			Dec.		
	ins.	ins.		ins.	ins.		ins.	ins.
1862	4.04	30.004	1843	3.71	29.938	1870	1.45	29.927
41	3.68	29.983	59	2.58	.957	49	1.44	.914
50	3.44	.978	68	2.38	30.019	69	1.41	.908
1843	0.23	30.033	1867	0.21	30.015	1861	0.05	29.914
48	0.22	.076	55	0.12	29.981	55	0.01	.962
61	0.11	.014	53	0.08	.989	62	0.00	.904

CAPE.

TABLE III.—Mean Monthly Readings of the Cape Barometer Reduced to 32° F., Sea Level and 45° Lat. (Index error of − 0·013 has been applied).

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1841	...	...	...	30·029	30·107	30·150	30·208	30·090	30·105	29·983	29·994	29·986	30·043
2	29·939	29·965	29·967	29·983	30·086	30·084	30·198	30·111	30·071	30·079	29·974	29·973	30·036
3	29·946	29·907	29·973	29·978	30·085	30·072	30·180	30·167	30·186	30·033	29·938	29.985	30·046
4	29·908	29·926	29·922	29·989	30·124	30·136	30·194	30·148	30·083	30·060	29·951	29·951	30·033
5	29·951	29·933	30·007	30·055	30·082	30·230	30·162	30·184	30·050	30·054	30·011	29·964	30·057
6	29·948	29·950	29·985	30·040	30·063	30·124	30·116	30·162	30·052	30·072	29·996	29·926	30·036
7	29·922	29·950	29·962	30·009	30·046	30·128	30·130	30·139	30·066	30·060	30·010	29.967	30·033
8	29·870	29.875	29·923	29·910	30·038	30·137	30·114	30·100	30·083	30·076	29·979	29·907	30·001
9	29·917	29·915	29·978	30·015	30·039	30·113	30·149	30·155	30·107	30·042	29·950	29·914	30·024
1850	29·898	29·925	29·953	29·969	30·040	30·055	30·055	30·150	30·079	29·978	30·006	29·961	30·006
Means	29·933	29·927	29·963	29·997	30·071	30·123	30·151	30·141	30·088	30·044	29·981	29·953	30·031

TABLE III.—*Continued.*

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1851	29·914	29·943	29·994	30·001	30·029	30·086	30·144	30·190	30·062	29·998	29·957	29·927	30·020
2	29·963	29·920	29·938	29·957	30·016	30·167	30·169	30·139	30·101	30·066	30·030	29·950	·035
3	29·955	29·924	29·962	29·995	30·091	30·135	30·206	30·109	30·187	30·058	29·989	29·944	·044
4	29·917	29·924	29·970	30·035	30·043	30·183	30·166	30·184	30·111	30·052 :	29·972	29·970	·046
5	29·938	29·943	29·973	30·064	30·142	30·116	30·213	30·074	30·098	30·051	29·981	29·962	·049
6	29·986	29·953	29·971	30·023	30·135	30·105	30·181	30·160	30·067	30·080	29·991	29·933	·040
7	29·928	29·922	29·955	30·057	30·074	30·038	30·169	30·183	30·093	30·086	29·986	29·988	·036
8	29·945	29·932	30·008	29·982	30·120	30·119	30·168	30·050	30·122	30·066	29·985	29·935	·036
9	29·916	29·943	29·965	30·052	29·969	30·118	30·155	30·164	30·038	30·019	29·957	29·958	·021
1860	29·949	29·887	29·956	30·051	30·052	30·092	30·120	30·098	30·048	30·034	30·019	29·935	·020
Means	29·941	29·929	29·969	30·022	30·067	30·116	30·169	30·135	30·093	30·051	29·987	29·950	30·035

TABLE III.—*Continued.*

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1861	29·899	29·921	29·957	30·000	30·010	30·091	30·167	30·140	30·054	30·014	29·989	29·914	30·013
2	29·926	29·913	29·965	29·945	30·053	29.952	30·066	30·118	30·057	30·004	29·981	29·904	29·990
3	29·918	29·900	29·920	29·982	30·103	30·139	30·163	30·132	30·121	30·001	30·013	29·939	30·028
4	29·925	29·887	29·981	30·042	30.032	30·083	30·170	30·128	30·105	30·010	30·003	29·942	30·027
5	29·963	29·927	29·934	30·022	30·054	30·208	30·121	30·120	30·062	29·991	30·061	29·925	30·032
6	29·921	29·876	29·943	30·008	30·108	30·117	30·218	30·052	30·150	30·039	29·987	29·971	30·033
7	29·901	29·942	29·954	29·995	30·076	30·131	30·129	30·129	30·135	30.067	30·015	29·941	30·035
8	29·902	29·928	29·997	30·051	30·033	30·179	30·153	30·116	30·071	30·051	30·019	29·981	30·040
9	29·914	29·942	29·966	30·064	30·029	30·061	30·190	30·215	30·074	30·030	29·979	29·908	30·031
1870	29·859	29·888	29·914	30·045	30·026	30·171	30·136	30·079	30·116	30·014	29·950	29·927	30·010
Means	29·913	29·912	29·953	30·015	30·052	30·113	30·151	30·123	30·095	30·022	30·000	29·935	30·024

TABLE III.—*Continued.*

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1871	29·901	29·905	29·974	30·035	30·027	30·136	30·141	30·082	30·081	30·048	29·976	29·942	30·021
2	29·923	29·953	29·922	29·994	30·018	30·169	30·120	30·029	30·123	29·998	29·975	29.899	30·010
3	29·846	29·920	29·954	30·012	30·000	30·120	30·094	30·096	30·094	30·048	30·003	29·938	30·010
4	29·915	29·924	29·913	30·027	30·109	30·205	30·221	30·121	30·104	30·043	29·968	29·947	30·041
5	29·901	29·898	29·921	30·016	30·031	30·098	30·259	30·114	30·110	30·067	29·981	29·953	30·029
6	29·890	29·912	29·962	30·044	30·111	30·148	30·153	30·122	30·117	30·138	29·997	29·992	30·049
7	29·971	29·962	29·951	29·993	29·983	30·176	30·125	30·124	30·107	30·014	29·962	29·975	30·029
8	29·951	29·975	29·912	30·028	30·060	30·119	30·084	30·182	30·085	29·977	29·977	29·957	30·026
9	29·926	29·929	30·004	30·032	30·028	30·094	30·142	30·147	30·088	30·037	29·971	29·910	30·026
1880	29·896	29·928	29·969	30·042	30·086	30·202	30·192	30·090	30·122	30·064	30·003	29·951	30·045
Means.	29·912	29·931	29·948	30·022	30·045	30·147	30·153	30·111	30·103	30·043	29·981	29·946	30·029

TABLE III.—*Continued.*

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1881	29·912	29·926	29·963	30·082	30·002	30·164	30·243	30·211	30·116	30·033	29·959	29·951	30·047
2	·942	·907	·980	30·006	30·081	·162	·174	·161	·111	·031	30·001	·910	·039
3	·925	·906	·963	29·962	30·002	·132	·153	·167	·080	·005	30·004	·980	·023
4	·945	·917	·963	29·984	30·054	·207	·224	·143	·107	·035	30·018	·953	·046
5	·948	·887	·969	29·981	30·082	·071	·142	·108	·074	·061	30·006	·966	·025
6	·909	·895	·947	29·998	30·098	·081	·189	·067	·068	·050	30·032	·958	·019
7	·925	·931	·975	30·051	30·088	·133	·149	·089	·126	·033	30·002	·978	·040
8	·968	·928	·995	29·984	29·994	·061	·182	·085	·116	·035	29·991	·978	·026
9	·918	·959	·993	29·975	30·053	·158	·195	·132	·103	·034	29·962	·901	·032
1890	·984	·856	·921	30·018	30·065	·129	·129	·131	·070	·077	30·020	·906	·026
Means	29·938	29·911	29·967	30·004	30·046	30·130	30·178	30·129	30·097	30·039	30·000	29·948	30·032

TABLE III.—*Continued.*

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1891	29·894	29·925	29·935	29·999	30.044	30·052	30·197	30·168	30·092	30·065	29·977	29·977	30·027
2	·887	·923	·932	30·017	·046	·108	·193	·039	·101	·038	·967	·930	·015
3	·877	·888	·966	·008	·058	·083	·142	·152	·041	·038	·992	·943	·016
4	·903	·897	·922	·073	·060	·097	·170	·099	·093	29·976	·980	·978	·021
5	·882	·900	·934	29·965	·080	·201	·119	·087	·084	30·038	·971	·912	·014
6	·936	·918	·954	·995	·063	·162	·161	·117	·075	·031	30·013	·984	·034
7	·904	·964	·904	30·038	·030	·221	·182	·127	·126	·033	·016	·956	·042
8	·899	·940	·907	·019	·077	·113	·127	·137	·101	·047	29·927	·978	·023
9	·913	·922	·946	·043	·097	·201	·040	·020	·151	·012	30·018	·949	·026
1900	·928	·951	·955	29·996	·058	·163	·042	·112	·093	·009	29·988	·928	·019
Means	29·902	29·923	29·936	30·015	30·061	30·140	30·137	30·106	30·096	30·029	29·985	29·954	30·024

TABLE III.—*Continued.*

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1901	29·921	29·921	29·967	30·029	30·066	30·120	30·148	30·118	30·138	30·079	29·967	29·954	30·036
2	·954	·935	·907	29.977	29·993	·120	·082	·105	·065	·072	30·026	30·001	·020
3	·929	·994	·985	30·000	30·050	·139	·174	·153	·080	·056	·031	29·926	·043
4	·914	·915	·920	29·993	·106	·124	·154	·111	·109	·006	·034	30·024	·034
5	·946	·991	·948	30·020	·073	·045	·158						

1854 Oct. Maclear gives 30·042.

To take into account Mr. Power's Correction of + 0·003 inches, all figures since 1847 (inclusive) should be increased by 0·003.

TABLE IV.

Mean monthly height of the Cape Barometer by Decades. Reduced to 32°F., Sea-Level and 45° Lat.
(An Index error of −0·013 inches has been applied).

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1841-50	29·933	29·927	29·963	*29·997*	**30·071**	30·123	30·151	**30·141**	*30·088*	30·044	*29·981*	29·953	30·031
1851-60	**·941**	·929	**·969**	**·022**	·067	·116	·169	·135	·093	**·051**	29·987	·950	**·035**
1861-70	·913	·912	·953	·015	·052	*·113*	·151	·123	·095	*·022*	**30·000**	*·935*	*·024*
1871-80	·912	**·931**	·948	**·022**	*·045*	**·147**	·153	·111	**·103**	·043	29·981	·946	·029
1881-90	·938	*·911*	·967	·004	·046	·130	**·178**	·129	·097	·039	**30·000**	·948	·032
1891-00	*·902*	·923	*·936*	·015	·061	·140	*·137*	*·106*	·096	·029	29·985	**·954**	*·024*
Means.	29·923	29·922	29·956	30·013	30·057	30·128	30·157	30·124	30·096	30·037	29·989	29·948	30·029

Heavier Type indicates highest monthly mean, italic type lowest ditto.

To take into account Mr. Power's correction of +0·003 in. since 1847 the means for 1841-50 should be increased by +0·001, the rest by +0·003.

TABLE V.

Deviations of the Cape Barometer Monthly Means (by Decades) from Mean of Decade.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1841-50 ...	− 98	−104	− 68	− 31	+ 40	+ 92	+123	+107	+ 61	+ 10	− 52	− 75
51-60 ...	94	106	66	13	32	81	134	100	58	16	48	85
61-70 ...	111	112	71	9	28	89	127	99	71	− 2	24	89
71-80 ...	117	98	81	7	16	118	124	82	74	+ 14	48	83
81-90 ...	94	121	65	28	14	98	146	97	65	7	32	84
91-00 ...	121	101	88	8	38	116	114	82	72	5	39	70
Means ...	−106	−107	− 73	− 16	+ 28	+ 99	+128	+ 94	+ 67	+ 8	− 41	− 81

(b) ST. HELENA, 1840-1847.

Long. 0h. 22m. 41.9s. W. of Greenwich or
„ 1h. 2m. 28.4s. W. of Göttingen.
Lat. —15° 56° 41.2′ S.
Height of barometer cistern above mean sea-level 1764-5 feet (by levelling).

The observations considered extend from 1840 May to 1847 July, with one interruption. They are published in detail in Sabine's "Observations made at the Mag. and Met. Observatory at St. Helena." Vols. I. and II. London, 1847-1860. The barometer was made by Newman according to a description given by the Royal Society. The internal diameter of the tube is 0.6ins. The scale terminating in an ivory point, is movable. The barometer would thus appear to be of the same type as that which is still in use at the Cape Observatory, but the latter has an internal diameter 0.1in. less. Until Sept., 1842, observations were taken at every even hour of Göttingen mean time, after that date until the conclusion of the series, at every hour. Observations were intermitted for 24 hours on Sundays and holidays. The barometer was moved in August, 1840, to a position 19 feet higher. The height given above is that of the barometer after removal. The observations of 1840, May-July, are reduced to 1764-5 feet.

Before leaving England, the barometer was compared with the Royal Society's Standard, and found to require a correction of -0.007ins. This correction includes the thermometer error. It was intended to make another comparison with the Standard after the conclusion of the observation, but no record of this having been done, has been found. In 1844, from 22nd April to 3rd May, simultaneous observations were made with another barometer near sea-level. The mean difference between the two barometers when corrected for all known errors, was found to be 1.786ins., which must be increased by 0.009 for reduction to sea-level, the lower barometer being 9.3 feet above sea-level.

Table 1 gives the mean monthly readings of the barometer at the above station reduced to 32° F. and Lat. 45°. No correction for decrease of gravity due to altitude has been applied,—this has not been necessary, as it is naturally included in the comparison with the barometer near sea-level.

The extreme readings of the barometer in each season (reduced as in Table 1) are:—

Season	Highest ins.		Lowest ins.		Range ins.
1840-41	28.388	on 24 July, '40	28.069	on 1 Mar, '41	0.319
41-42	.388	on 9 June, '42	.045	on 24 Nov, '41	.343
42-43	.440	on 9 July, '42	.037	on 14 Mar, '43	.403
43-44	.408	on 27 Aug, '43	.044	on 28 Dec, '43	.364
44-45	.426	on 15 July, '44.	.085	on 21 Dec, '44	.341
45-46	.391	on 13 July, '45	.050	on 14 Mar, '46	.341
46-47	.405	on 17 July, '46	.056	on 20 Jan, '47	.349

Table 1 shows that in the mean the lowest barometer occurs in March and the highest in July. The means can be represented by a Fourier series. As the calendar months are of varying lengths, we should not assume that the mean of any month is the mean of the corresponding one-twelfth of the year. The introduction of a rational calendar is probably out of the question. Such a one is as follows :—

January	to have	30	days.		
February	,, ,,	30	,,	or 31 days in leap year.
March	,, ,,	30	,,	
April	,, ,,	31	,,	
May	,, ,,	30	,,	
June	,, ,,	31	,,	
July	,, ,,	30	,,	
August	,, ,,	31	,,	
September	,, ,,	30	,,	
October	,, ,,	31	,,	
November	,, ,,	31	,,	
December	,, ,,	31	,,	

This calendar would coincide with the present one on Jan. 1st, April 1st, June 1st, and from August 1st to the end of the year. The quarters and half-years would compare as follows :—

	Rational.	Present.
1st quarter	90 or 91 days.	90 or 91 days.
2nd ,,	92 ,,	91 ,,
3rd ,,	91 ,,	92 ,,
4th ,,	92 ,,	92 ,,
1st half-year	182 or 183 ,,	181 or 182 ,,
2nd ,,	183 ,,	184 ,,

With this rational calendar, the derivation of the co-efficients of a Fourier series by the assumption that each month is a twelfth of a year would be sufficiently exact for all purposes.

In taking monthly means, some meteorologists transfer the last day of January and the first of March to February.

But if we keep to the means of the calendar months, we can make use of the formulæ developed by Mons. A. Angot in the *Annales du Bureau Central Meteorologique de France*, 1887., Vol. I., pp. B227-B236. This course has not been followed here, as it would be a refinement not warranted by the material at our disposal, and, indeed, we did not know of Angot's formulæ when the computations were made. Where θ is measured from the middle of January, we find that the expression

$$\begin{aligned} 28.2210 - 544 \cos \theta &- 190 \sin \theta. \\ +198 \cos 2\theta &+ 7 \sin 2\theta. \\ -21 \cos 3\theta &- 47 \sin 3\theta. \end{aligned}$$

represents the mean monthly height of the barometer at St. Helena as follows:—

	Computation.	Observation.	Residual. (unit 0.001in.).
July	22.298in.	22.300in.	−3
Aug.	.294	.292	+2
Sept.	.254	.253	+1
Oct.	.215	.218	−3
Nov.	.202	.199	+3
Dec.	.197	.192	+5
Jan.	22.185	22.180	+5
Feb.	.169	.174	−5
Mar.	.169	168	+1
Apl.	.186	.187	−1
May	.219	.222	−3
June	.265	.270	−5

As the average deviation of any given month is about 0.012in. from the mean of a series of years, the above representation is satisfactory.

In considering the diurnal variation of the barometer at St. Helena we have confined ourselves to the period during which hourly readings were taken. Allowance has been made for the difference of height in the mercury between the first and last readings in each month, so that the annual variation of the barometer has been eliminated. After the calculations had been completed, it was found that Mons. Angot had also derived the figures. A comparison with Mons. Angot's table (*Annales du Bureau*, 1889, Vol. I., p.B250) shows that our figures, though in the main following his very closely, sometimes deviate by quantities up to 0.005ins. These differences may arise from two causes, (1) in the published observations a considerable number of errors or misprints were found, and it is probable others have escaped detection by either of us, (2) Mons. Angot probably incorporated the two-hourly series.

If we represent the deviation at any hour from mean of day by the series

$$C_1 \cos h + C_2 \cos 2h + C_3 \cos 3h + \text{etc.}$$
$$+ S_1 \sin h + S_2 \cos 2h + S_3 \sin 3h + \text{etc.}$$

we find the values given in Table III.

The above formula can be transformed to

$$a_1 \sin (h + A_1) + a_2 \sin (2h + A_2) + \text{etc.}$$

The co-efficients in this case are furnished in Table IV. Mons. Angot gives the latter co-efficients up to a_4 and A_4 reduced to true time. The reduction to true time may amount to 15° in the case of A_4.

A priori, the introduction of true solar time seems to be correct in principle, but the figures do not show improvement. The angle A_2 is the most constant; in Table IV. it shows an extreme range of 9°, whereas by reducing to true time, the range will be increased to 13°.

It is tempting to find if the co-efficients of Tables III. and IV. can be represented by a Fourier series. The partial results of such an attempt will be found in Table V., in which θ is measured from the middle of January. The results are not satisfactory. The co-efficients of the different terms vary so irregularly that it is plain that the variations of the barometer are not simple functions of the Sun's longitude. If we attempt to exhibit the equation of time by a simple series in which the variable is the Sun's mean longitude, we come on similar irregular co-efficients. It is, of course, possible to exhibit the equation of time with great exactitude by such a series, but it would throw no light on its causes, which we know reside in the obliquity of the ecliptic, the excentricity of the Earth's orbit and the position of the perihelion. But we do not yet know all the causes of the diurnal variation of the barometer.

There is the very great difficulty of finding the true height of the barometer freed from temperature effects. The usual method of correcting a barometer for temperature can only be considered a first approximation. Probably each barometer has its own secondary corrections due to lag, etc. Herein consists the great advantage of the Sprung barograph, which records in effect the varying weight of the mercury. It therefore requires no correction of the first order for temperature, and the correction for terms of the second order is easily made mechanically.

It is impossible to say how much of the smaller terms of Table III. are due to the residual temperature effects.

TABLE I.—Barometer Readings at St. Helena (reduced to 32° F. and Lat. 45°, and to the Royal Society's Standard). The mean reduction to mean sea-level is + 1·795 inches.

28 inches +

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Mean.
1839-40	...	...	...	...	...	...	...	...	...	...	·226	·284	...
40-41	·322	...	·256	·188	·202	·192	·171	·184	·165	·168	·215	·258	·219
41-42	·281	·275	·252	·206	·169	·176	·174	·153	·172	·177	·219	·258	·209
42-43	·332	·300	·248	·222	·194	·206	·181	·158	·157	·194	·235	·278	·225
43-44	·284	·301	·271	·222	·194	·194	·183	·162	·142	·173	·201	·262	·216
44-45	·307	·293	·235	·228	·208	·190	·197	·188	·209	·211	·232	·308	·234
45-46	·310	·294	·272	·238	·218	·196	·192	·188	·177	·182	·229	·258	·230
46-47	·298	·290	·236	·220	·208	·187	·162	·188	·157	·202	·217	·258	.219
47-48	·263	...	...	...	...	...	...	...	...	...	...	...	...
Means	·300	·292	·253	·218	·199	·192	·180	·174	·168	·187	·222	·270	·221

TABLE II.

Reading of the Barometer (reduced to 32° F.) minus mean of day. The Barometer was not read at the exact hour, but at $2\frac{1}{2}$ mins. before; thus midnight is really $11^h\ 57\frac{1}{2}^m$ p.m.

(Unit = 0·0001 inches.)

Hour.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Midn.	+ 45	+100	+119	+112	+ 88	+ 81	+112	+131	+163	+ 96	+ 62	+ 72
1	−128	− 42	− 15	− 22	− 16	10	20	7	− 6	− 76	−119	−119
2	249	177	153	147	127	−115	−100	−120	150	229	259	244
3	305	252	252	228	218	221	203	216	245	332	316	311
4	287	239	282	254	248	241	238	252	290	322	293	296
5	168	171	207	212	204	211	208	228	238	239	207	176
6	+ 12	43	84	67	99	133	139	117	121	108	30	+ 8
7	185	+121	+ 74	+106	+ 60	6	19	+ 12	+ 36	+ 82	+148	179
8	292	262	249	269	217	+170	+141	162	181	238	273	286
9	355	367	369	389	366	310	293	310	289	330	357	354
10	342	371	388	446	407	347	324	356	326	329	351	347
11	272	318	336	346	323	278	262	276	263	274	291	284
Noon.	172	213	201	164	157	139	117	125	110	153	183	180
13	47	39	3	− 15	− 36	− 35	− 42	− 39	− 48	− 12	27	45
14	−107	−118	−165	184	206	183	197	195	205	159	−133	−103
15	247	260	289	317	288	246	262	285	309	257	248	246
16	324	337	340	340	298	248	243	280	306	286	314	336
17	299	333	322	299	245	182	165	217	237	236	288	318
18	209	258	236	228	171	106	96	144	144	134	200	223
19	75	147	104	108	64	5	1	21	9	3	62	84
20	+ 60	+ 9	+ 40	+ 48	+ 76	+ 85	+ 96	+105	+138	+129	+ 90	+ 56
21	168	128	180	158	169	164	174	191	251	231	204	171
22	244	230	264	199	194	197	204	231	287	293	277	259
23	204	219	226	184	163	154	170	208	264	237	206	215

TABLE III.

DIURNAL VARIATION OF THE BAROMETER AT ST. HELENA.

Unit=0·0001 inch.

Month	C_1	S_1	C_2	S_2	C_3	S_3	C_4	S_4	C_5	S_5	C_6	S_6	C_7	S_7	C_8	S_8	C_9	S_9	C_{10}	S_{10}	C_{11}	S_{11}	C_{12}
July	+10·2	−18·0	+116·4	222·6	−6·2	−44·8	+0·6	−15·0	−0·5	−2·4	−0·9	+10·4	+1·3	+1·3	−0·5	+0·4	+0·3	−1·5	+0·5	+0·1	−2·7	−0·2	−1·6
Aug.	10·0	32·0	130·8	245·9	7·2	30·9	−0·8	13·2	4·0	3·0	1·7	4·2	−1·8	5·9	0·6	1·7	1·3	2·1	0·1	−0·4	1·3	+1·4	+0·2
Sep.	−8·4	20·5	133·8	272·2	10·4	11·7	+3·7	9·5	+2·2	+0·2	+0·2	0·9	6·4	3·3	0·8	−1·9	3·0	+0·1	0·7	0·4	0·4	−0·3	−0·9
Oct.	+38·8	13·5	119·8	287·2	16·9	+10·0	4·3	5·7	2·2	6·4	1·4	−0·2	+4·2	−2·6	2·6	0·8	+2·1	0·0	1·6	0·5	1·8	1·3	+0·1
Nov.	65·7	58·8	118·3	286·2	10·4	34·2	1·7	4·2	4·7	6·4	−0·4	3·8	0·1	+0·9	+1·5	+3·0	3·6	−2·8	0·8	+1·1	3·1	0·4	0·6
Dec.	66·4	74·0	121·3	277·7	14·8	46·2	8·1	+2·7	3·6	8·3	6·8	6·7	3·3	3·4	0·6	−0·4	1·2	1·2	2·3	0·5	5·6	1·0	0·5
Jan.	72·8	72·8	100·2	274·3	13·4	43·8	6·9	2·9	2·6	10·6	6·2	4·9	0·2	4·9	−1·1	0·1	2·0	0·3	0·6	0·6	0·8	0·8	−0·7
Feb.	60·7	96·2	153·4	252·1	12·7	20·8	2·6	−8·0	0·2	7·8	+0·2	0·9	2·6	−0·2	0·6	0·9	5·7	1·4	−0·2	0·6	0·1	2·9	+1·1
Mar.	41·8	76·5	161·2	271·3	10·9	0·1	1·1	9·7	3·9	0·5	−2·2	+1·4	6·2	1·3	+1·0	1·2	0·6	2·8	+1·1	+0·2	+0·6	1·3	0·1
April	50·0	93·0	144·8	272·0	13·4	21·1	4·1	8·9	1·1	−3·0	1·7	1·3	11·5	+3·2	2·1	+0·5	0·4	0·6	−0·4	0·3	0·2	+1·8	1·5
May	39·8	64·8	128·6	255·8	6·0	35·0	5·9	13·6	2·1	6·7	0·5	4·8	2·3	2·1	+0·5	0·1	+2·3	+1·7	+0·6	0·2	1·3	−0·9	−0·8
June	28·3	24·7	116·6	228·0	5·8	42·0	2·4	12·7	−1·2	3·0	1·5	8·5	+5·1	−2·8	1·5	1·9	2·5	−1·6	0·4	1·3	+0·1	+2·0	0·8

TABLE IV.

Diurnal Variation of the Barometer at St. Helena.
(Unit = 0·0001 in.).

	a_1	A_1	a_2	A_2	a_3	A_3	a_4	A_4	a_5	A_5	a_6	A_6	a_7	A_7
Jan. ...	106	315°	295	158°	46	163°	7	67°	11	194°	8	232°	5	182°
Feb. ...	114	328	295	149	24	149	8	162	8	182	1	168	3	274
March ...	87	331	316	149	11	90	10	186	4	263	3	302	6	282
April ...	106	332	308	152	25	32	10	205	3	340	2	308	12	164
May ...	76	328	286	153	36	10	15	204	7	343	5	354	3	138
June ...	38	311	256	153	42	8	13	191	3	22	9	350	6	299
July ...	21	330	251	152	45	8	15	179	2	12	10	355	2	225
Aug. ...	34	343	279	152	32	13	13	184	5	53	4	338	6	163
Sept. ...	22	22	303	154	16	42	10	160	2	265	1	12	7	173
Oct. ...	41	289	311	157	20	149	7	143	7	199	1	98	5	304
Nov. ...	85	309	310	157	36	163	4	158	8	216	4	186	1	186
Dec. ...	99	318	303	156	48	162	9	72	9	204	10	225	5	223

TABLE V.

Seasonal Variation of the Coefficients of the Diurnal Variation of the Barometer as functions of the Sun's mean Longitude. (Unit = 0·0001 inch).

Coefficient.	Constant Term.	cos θ	sin θ	cos 2 θ	sin 2 θ	cos 3 θ	sin 3 θ
C_1	+ 39·7	+ 29·6	+ 6·4	+ 1·2	− 13·9	− 2·2	+ 0·2
S_1	− 53·4	− 14·6	− 24·2	1·7	0·6	2·0	10·8
C_2	+ 129·5	+ 4·2	+ 11·1	− 8·1	+ 13·6	4·0	− 1·2
S_2	− 262·1	− 19·1	10·7	+ 17·2	0·9	3·7	+ 4·7
C_3	10·7	3·7	1·4	1·6	− 0·6	0·4	0·0
S_3	2·5	+ 41·7	− 16·6	2·2	3·7	+ 1·3	− 0·9
C_4	+ 1·1	3·3	3·8	2·0	+ 0·4	0·6	+ 0·2
S_4	− 7·9	6·7	2·8	0·9	− 1·8	1·5	− 1·2

(c) DURBAN, NATAL OBSERVATORY, 1873-1905.

The monthly means given in the table are derived from two sets of observations. From 1873-1883 the readings were taken in the Botanical Gardens, Durban, which are close to the Observatory, (Govt. Astronomer's Report for 1903). Observations were made at 9 a.m. and 3 p.m. It has been assumed from the observations themselves, that in the mean the difference of the reading 9 a.m.-3 p.m. is as follows:—

Jan.	- 0.043in.	July	- 0.055in.
Feb.	45	Aug.	60
Mar.	48	Sept.	57
Apl.	55	Oct.	55
May	54	Nov.	53
June	50	Dec.	46

The mean of the 3 p.m. readings thus increased, and the 9 a.m. readings has been taken as the 9 a.m. reading. When this mean deviates more than 0.015in. from the 9 a.m. reading : is added as added to the figures printed in Table 1. It has been further assumed that in the mean of 11 years, these readings reduced to sea-level should agree with the mean of all the reduced readings taken at the Durban Observatory. To force this agreement - 0.038in. has been applied to all the readings taken at the Botanical Gardens. The observations since 1884 have been made at the Natal Observatory. In deriving the 9 a.m. means, we have in general three sets of figures, viz., the 8 a.m. readings published by the Cape Meteorological Commission, and the 9 a.m. and 3 p.m. readings published by the Government Astronomer. It has been assumed that in the mean the difference between the 9 a.m. reading and the 8 a.m. and 3 p.m. readings are as follows:—

	8 a.m.	3 p.m.		8 a.m.	3 p.m.
Jany.	+0.038in.	+0.050in.	July	+0.031in.	+0.075in.
Feby.	38	55	Aug.	32	77
Mar.	37	60	Sept.	34	78
Apl.	36	64	Oct.	35	73
May	33	68	Nov.	36	66
July	32	72	Dec.	37	55

The mean 9 a.m. reading is the mean of the three reduced readings, but discordant readings have been rejected. The heights of the Durban barometers have been

261 feet to Nov., 1884.
250 ,, to 31st Dec., 1896.
262 ,, from 1st Jan., 1897.

The reduction from mean of year at 9 a.m. to mean of day is about - 0.033 inches.

I have to thank Mr. Nevill and Mr. Fermor Rendell for their assistance in clearing up some doubtful printings and readings.

TABLE I.—Mean Monthly Readings of the Durban Barometer at 9 a.m., reduced to 32° F., sea-level and gravity of 45° Lat.

Year.	Jan.	Feb	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1873	29·871	29·976	30·022	30·066	30·060	30·206	30·185	30·200 :	30·156 :	30·082	30·048	30·009	30·073
4	30·030	30·025 :	30·004	·052	·152	·280	·197	·193	·200 :	30·086	30·013	29·992	·102
5	30·014	30·014	30·052	·097	·165 :	·182	·276	·170	·145	30·113	30·055	30·032	·110
6	29·994	29·983	30·061	·162	·171	·247	·268	·169	·131	30·158	30·036	29·945	·110
7	30·019	29·997 :	30·046 :	·110	·047	·277	·270	·211	·175	30·138 :	30·020	29·992	·109
8	29·997	30·042	30·100	·157	·113	·176	·118	·216	·109	29·978	30·073 :	29·973	·089
9	29·962	30·035	30·059 :	·126	·177	·129	·192	·227	·127	30·075	29·955 :	29·900	·081
1880	29·906 :	29·932	30·060	·011	·153 :	·277 :	·295 :	·093	·123	30·135	30·008	30·002	·083
Mean	29·974	30·000	30·050	30·097	30·130	30·222	30·225	30·185	30·146	30·096	30·026	29·981	30·094

TABLE I.—*Continued.*

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1881	29·972	30·017	30·026	30·130	30.002	30·255	30·195	30·188	30·183	30·078	29·983	29·978	30·084
2	29·973	30·028	·061	·048:	30·114	·230	·252	·240	·154	·087	30·063	30.020	·106
3	30·018	29·998	·064	·079	30·107	·240	·210	·191	·118	·127	30·066	30·003	·101
4	30·014	29·983	·021	·093	30·129	·268	·280	·292	·124	·090	29·997	30·032	·110
5	30·027	29·971	·074	·054	30·117	·207	·255	·159	·176	·128	30·043	29·996	·101
6	29·960	29·969	·037	·113	30·169	·192	·267	·172	·183	·044	30·085	30·027	·102
7	29·988	30·023	·077	·145	30·207	·313	·222	·154	·273	·102	30·093	29·997	·133
8	30·033	30·014	·117	·066	29·997	·171	·272	·144	·241	·085	29·985	30·035	·097
9	29·992	30·039	·060	·075	30·133	·282	·255	·258	·165	·179	29·991	29·962	·116
1890	29·961	29·935	·071	·102	30·146	·281	·193	·176	·191	·166	30·037	30·002	·105
Mean.	29·994	29·998	30·061	30·090	30·112	30·244	30·240	30·197	30·181	30·109	30·034	30·005	30·105

TABLE I.—*Continued.*

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1891	29·991	29·958	30·073	30·121	30·100	30·152	30·334	30·254	30·143	·167	30·066	29·997	30·113
2	29·928	29·959	30·005	·066	·118	·138	·259	·151	·089	·078	29·973	29·948	·059
3	29·925	29·979	30·090	·075	·197	·176	·272	·186	·090	·090	30·017	29·990	·091
4	30·001	30·051	30·001	·163	·183	·183	·214	·217	·180	·041	30·025	30·033	·108
5	30·003	29·985	30·056	·099	·173	·266	·173	·164	·144	·089	30·017	29·958	·094
6	29·980	30·017	30·029	·085	·205	·195	·257	·213	·114	·106	30·072	30·012	·107
7	30·009	30·050	30·000	·140	·143	·282	·139	·243	·138	·044	29·970	29·980	·095
8	29·907	30·058	29·997	·118	·140	·253	·229	·323	·129	·046	29·947	29·981	·094
9	29·950	29·975	30·054	·148	·276	·328	·253	·156	·186	·067	30·078	29·983	·121
1900	29·953	30·057	30·033	·108	·130	·285	·194	·156	·183	·035	30·006	29·964	·092
Mean.	29·965	30·009	30·034	30·112	30·166	30·226	30·232	30·206	30·140	·076	·017	29·985	30·097

TABLE I. *Continued.*

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1901	29·900	30·006	30·060	30·102	30·157	30·303	30·233	30·249	30·217	30·147	30·004	29·964	30·112
2	·950	30·021	·016	·028	·172	·132	·187	·129	·130	·161	·020	30·041	·082
3	·960	30·047	·010	·046	·063	·183	·248	·191	·261	·042	·002	29·978	·086
4	·961	29·990	·034	·058	·161	·197	·270	·182	·190	·026	·017	30·048	·094
5	·976	30·027	·099	·136	·102	·080	.310	·194	·064	·065	·080	29·981	·093
Mean	29·949	30·018	30·044	30·074	30·131	30·179	30·250	30·189	30·172	30·088	30·025	30·002	30·093

TABLE II.

Durban Barometer. Deviation of Monthly Means (9 a.m.) from Means of Years.

Years.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1873-80	− 120	− 94	− 44	+ 3	+ 36	+ 128	+ 131	+ 91	+ 52	+ 2	− 68	− 113	30·094
81-90	111	107	44	− 15	7	139	135	92	76	4	71	100	·105
91-00	132	88	63	+ 17	69	129	135	109	43	− 21	80	112	·097
1901-05	144	75	49	− 19	38	86	157	96	79	5	68	91	·093

5—RECENT COMETARY OBSERVATIONS.

By R. Fermor Rendell, B.A., F.R.A.S., of the Observatory, Durban, Natal.

Note.—This paper has been published in the monthly Notices of the Royal Astronomical Society for May, 1906.

6.—ON SOME METEOROLOGICAL FEATURES OF SOUTHERN RHODESIA.

By Rev. E. Goetz, S.J.

The object of this paper is to give a general idea of the meteorological conditions prevailing on the Rhodesian tableland. Observations have been taken in Bulawayo since February 1897, but the observations from January 1904 to January 1906 only have been used for the present paper, as these only have been controlled by recording instruments. The data from the recording sheets have not been tabulated, and I am not able to give at present more than a summary of the results likely to be gathered from them.

A mere glance at the Anemometer traces shows a large predominance of wind in the East quarter, the main winds of the year ranging from E. to S.E., E. and E.S.E. having a prevailing character. The records seem to show one kind of disturbance only, which is the diurnal rotation of the wind. This rotation is very frequent here, and, as far as we are concerned, of great importance. Other disturbances are so rare that they cannot have any appreciable effect on the main results.

Taking, therefore, the anemometer records as a guide, I find that we have two main weather periods, one of winds in the East quarter, and one of daily veering winds. There is often a transition period from one to the other when the wind veers from E. to N. or N.E. during the hot hours of the day.

In the East wind periods the main wind seems to be E.S.E.; in fact, the vane remains for days together parallel to the streets of Bulawayo, which run 14 degrees S. of E. South-east winds also occur, but the wind hardly ever remains in a more southerly direction for any length of time. There is often a veering of the vane from E. or E.S.E. to a point more south during the day with a motion back to its original position after a few hours. The strength of the wind ranges from one to four on the Beaufort Scale, stronger winds are rare and calms also; out of 1009 hours of calm registered in the two years under consideration, only 48 fell in these periods or on periods of East wind with some North in the middle of the day. Most of those calms were of short duration, the longest being one of seven and one of eight hours.

The periods of daily veering winds are shorter than the preceding ones. There were on the whole 84 such periods, giving a total of 234 days out of 731. In these periods the wind is generally Easterly during night; after sunrise, some time between 7 and 10 a.m., the vane turns North; in the afternoon it is West, and some time late in the afternoon or at night we find it South; and, during night, it completes the rotation to East. This is, of course, the main tendency of the wind on those days. The passage from one quarter to the other is often very rapid, and calms are frequently taking the place of one quarter, especially in the passage from West to South. The rotation is practically always diurnal; on three occasions only, did it take two days to complete it, and now and then it took place in the space of a few hours. Strong winds are rare. Practically all the

hours of calm, 961 out of 1009, occurred in these periods. Besides these rotations, I have noted about half-a-dozen clear movements from East through South to South-West and back, or right round through South in the course of a day.

The veerings of the vane from E. or E.S.E. to N.E. or N. in the middle of the day and back in the afternoon are not rare. The behaviour of the barometer, thermometer, and hygrometer traces induce me to think that they ought to be classed in the complete rotation periods through North.

The importance for us of these diurnal rotation periods comes from the fact that over 80 per cent. of the rains in these two years fell in this weather type.

From January, 1904, to January, 1906, the rainfall has been 31.61ins. distributed in the following way:—

4.89ins. in the East wind periods.

4.41ins. in the periods of East wind with several hours of N.E. or N. in the day.

21.78ins. in the daily rotation periods.

.53ins. on one rotation of the wind through South.

This gives 70 per cent. for the veering wind periods alone, and 84 per cent. if we consider them with those in which there was a notable amount of N. or N.E. wind.

A more accurate discussion will very likely show that the amount of rain due to the East wind periods is even less than 15 per cent., as I find that a fair portion of the 4.89ins. fell in the passage from the veering periods to the East wind periods, and ought to be considered as part of the rains of the preceding day.

There is a marked difference between the two sets of rains; the east rains are mostly drizzles, amounting at the highest to one or two-tenths of an inch in 24 hours. They are generally less than one-tenth. Occasionally they turn into a slow, steady rain. On only one occasion was there a record of more than one inch, 1.28ins., in one of the east wind periods, and most of this fell in the first day of it.

The rains in the other periods are almost all heavy rains connected with thunderstorms. Nearly all the thunderstorms noted in the meteorological register are on days when the wind was veering, a few on the days when N. or N.E. was very prominent, two on the first day of some east wind periods. Thunder and lightning without storm or rain occur very frequently, very rarely with pure east winds. Slow, steady rains are rare with veering winds, and are almost always the clearing rains after a thunderstorm. The fact that most of our rains come from thunderstorms explains why they have a very local character and why stations very little distant from one another and in practically the same geographical position show rather marked differences in the rain (v.g., Jan., 1906, rainfall at the Observatory 10.11ins.; at the Waterworks, two miles away, 7.25ins.).

This seems also to confirm the general idea that the Rhodesian rains are due to the North and West winds. This question of the origin of the rains in Rhodesia is not, however, easily settled. Mr.

Sutton and Mr. Stewart * strongly oppose the prevalent theory which maintains that the moisture-laden winds from the Indian Ocean are the primary source of the South African rains. "Our rain," writes Mr. Sutton (for Cape Colony) "originates on the Equator, being carried hither in the upper atmospheric currents flowing from West and North. The rain begins on the East Coast when the moist upper stratum meets the lower bodies of air, damp with the moisture from the Indian Ocean. Then it gradually works back from the East coast as the Eastern air becomes heavier with vapour."

The idea that the rains are due to a mixture of the upper and lower currents seems to me to explain, partly, at least, what takes place in South-Western Rhodesia. Rain occurs here mostly when the conditions for such a mixture are fulfilled, i.e., when there is a barometric depression and an increase of temperature during the periods of North or veering winds. There is then a double reason for an upward movement of the lower air. Judging from the cloud observations taken at 8 a.m. and 8 p.m. during the last two years, I think that the shell of the atmosphere affected by the lower currents must be rather shallow, and that a small change in the temperature and pressure will, on that account, force very rapidly the lower current into the upper one. The higher and middle clouds move, we may say, invariably in the same direction, which is Eastwards from a point perhaps slightly North of West. This direction is, as far as I can judge, constant the whole year round.

As I shall show later, the mean surface wind is almost exactly opposite, blowing from a point between E. and E.S.E. This, however, leaves open the question whether the moisture comes originally from the upper West or North-West current or from the lower easterly one. I incline to believe that a great part, the greater part, perhaps, of the moisture comes direct from the Indian Ocean by the East and South-East winds. These, as a rule, it is true, give us clear weather, but there are several indications which point out that they must be rich in moisture which is to be condensed and brought down as rain. There is, first, the fact that the mean relative humidity is generally higher in the East wind periods than in the others, and that, even in the rainy season, when there is little or no rain in the former, whilst there is often a large amount in the latter. It would, however, be advisable to study the dew point and the absolute humidity in connection with the relative humidity to settle satisfactorily the question whether the East winds are really more moist than the others. Another fact also is that a drop in the temperature readily brings forth clouds on East wind days. There is here a particular kind of cold weather for which the natives have a special name; they call it "Amakassa." It is exclusively connected with East to South-East winds. On these occasions we have very low, fast-moving cumulus clouds of ragged appearance. They often coalesce into a cumulostratus, covering the whole sky and invariably move in the same direction as the surface wind. They

"An introduction to the study of S.A. Rainfall." J. R. Sutton. *Trans. of S.A. Phil. Soc.* Vol. XV. P.I. "Meteorology in South Africa," Ch. Stewart.

rarely give an appreciable rain, though the air is unpleasantly damp. Drizzles, lasting two or three days, and yielding anything from zero to one-tenth of an inch per day is the most they give us. During that time the Hygrometer remains very high, and evaporation below the average even with high wind. This kind of weather is a noted featuie of the Rhodesian climate; no data are, however, available to decide whether it could be traced right to the Indian Ocean or whether it might not be due to rains further South or South-East. These reasons would make me hesitate to accept on the whole for Rhodesia Mr. Sutton's theory of the Cape rains. *

It will be of interest to compare the other records with the Anemometer sheets. The Barometer, Thermometer, and Hygrometer show a distinct periodic movement, and a comparison with the winds shows a very close synchronism with the wind periods.

To demonstrate this roughly, I have drawn up the following table of means for each wind period :— †

Mean of Mercurial Barometer reading at 8 a.m. reduced to 32° Fahr.:

Mean Temperature by formula ... ... $\frac{\text{Max.} + \text{Min.}}{2.}$

Mean Black Bulb Thermometer readings:

Mean Relative Humidity by the formula ... $\frac{\text{Max.} + \text{Min.}}{2.}$

read off a Richard Hair Hygrometer sheet.

For all these means I have followed the wind periods except now and then for the hygrometer. I found there that the humidity curves have a different appearance with the different winds, but that the change from one period to another does not always coincide exactly with the changes in the other elements.

There is sometimes a difference of 24 hours, sometimes, on the contrary, the changes in the Hygrometer follow very closely the wind variations. In cases where I found only one day's difference in the periods, I put the day of transition now in one and now in the other period, according to the shape of the curve. The mean relative humidity, calculated in this way, is, of course, liable to be very erroneous in the rainy season; but I do not want absolute figures, I only want to find the way in which the quantity varies. In the dry season from the beginning of April to the end of October, the mean relative humidity does not differ very much from the mean of the highest and lowest readings of the day.

The general result of this tabulation may be stated as follows: A period of easterly winds corresponds to a high barometer, low temperature (both air and sun temperature) and a high Relative Humidity. A period of veering wind to a low barometer a high temperature and a low Relative Humidity.

Out of 84 periods in which there was a daily veering of the winds round the compass 65 fall between two high barometers, 3 between two low barometers, and the others on a rising or falling barometer.

* At Boroma, near Tete, on the Portuguese Zambezi, latitude 16° North East of us, I find that half the rainfall of 1891-92 is attributed to S.E. winds. I have not yet seen the later rainfall returns.

† See Appendix.

The fluctuation of the barometer is very small at Bulawayo (Lat. 20° 9′). The mean of the extreme ranges for eight years gives only .222 of an inch. The difference between two consecutive days in the two years under consideration was nearly always under .1, the highest was .158.

The correspondence in even this summary handling of the figures, between barometer and wind changes, points out the importance of relatively small pressure variations in these latitudes.

The air temperature results show on the whole the truth of the statement that a low temperature corresponds to East winds; there are more inversions, however, than in the pressure figures, but the Black Bulb temperatures show a remarkable correlation. Out of 70 periods of daily veering winds which occurred from April, 1904, to November 9th, 1905, during which time the Black Bulb readings were taken, 54 show a higher temperature than in the East Winds that preceded or followed. The differences are sometimes very large, especially in the rainy season. Clouds covering the sky in the middle of the day may partly account for this great difference, but in the rainy months clouds appear after 10 a.m. nearly every day, so that the chances may be said to be equally distributed. But the same sequence of high and low temperatures, though with smaller differences, is observed in the clearer months, for instance in July and August, when the cloudiness comes down to 1.1.

The variations of the Relative Humidity are also very interesting. Even in the rainy season, with a large amount of rain in the low barometer periods, there is a marked lower Relative Humidity than on high barometer and East wind periods. The temperature variations partly account for that, but not completely, I think. The East Wind must be more saturated with moisture, although a large amount of it has often been deposited on the high lands of the Eastern coast. To settle this point satisfactorily, the dew point and absolute humidity figures would be required. It might be said also that the greater relative humidity corresponding then to the East winds may be considered as the effect of the rains that fell in the preceding days, especially as the rains setting in from some other direction with thunderstorms, often continue as slow rains with winds ranging from E. to S. But the same sequence of high relative humidities with easterly winds and low ones with other winds is prevailing with much more marked differences in the dry season when no rain falls. The Relative Humidity curves show a peculiarity worth mentioning. During East Winds the amplitude is very great, ranging often from 10 per cent. or lower to 90 per cent. or over, whilst during the other periods the daily curve is very contracted round the mean of the day, the maximum remaining considerably lower than the maximum during the East Winds.

Special mention ought to be made of the periods in which the wind passes from E.S.E. or E. to N.E. or N. in the middle of the day and back, usually some time in the afternoon before sunset. This might correspond to the law which Dr. Sprung* gives in his

* Lehrbuch der Meteorologie. 1885 p. 345.

meteorology, for the Northern Hemisphere, when he says: "On plains or also on highlands the wind shews a tendency to turn with the hands of the clock in the forenoon and the other way in the afternoon." I believe that this particular wind veering is only the beginning of a rotation. For these periods almost invariably are the passages of a low barometer, a high temperature, and a low Relative Humidity to a high barometer, a low temperature and a high Relative Humidity or *vice versâ*. Sometimes they are on a slight rise in a low barometer, sometimes on a slight depression in a high one. On the whole, comparing the various elements connected with a veering wind period in the table given as an appendix to this paper, we see that these East with North wind periods, differ little from the rotating wind periods. These might also be the passages of secondary cyclones or V depressions, with their usual thunderstorms. Observations from other centres would, however, be wanted to decide the point.

In order to give a more precise idea of the winds of Bulawayo, I have calculated the North and East components of wind frequency and wind movement for the three months of October, 1903 to 1905. The extreme regularity of our climate shown by the traces of the recording instruments allows me to assume that the computation for one month only and even in the short period of three years will fairly well bring out the general features of the wind movement. October is besides likely to be the best month to give average results, as it is astride on the two seasons of the year.

The first three columns of the following Table (A) represent the wind frequency, the next three the combined frequency and movement. The co-efficients for the various directions are in the former the number of times the wind blew in each direction, in the latter the velocity in kilometers per hour for each direction.

TABLE A.

	Wind frequency Components.			Movement Components.		
Hour.	N.	E.	Resultant.	N.	E.	Res.
0	− 21·7	+ 65·7	69·2	− 267	+ 997	1,032
2	− 12·4	69·8	70·9	− 159	1,009	1,021
4	− 10·4	64·0	64·8	− 154	887	900
6	− 5·7	65·3	65·5	− 214	996	1,019
8	+ 29·5	53·0	59·6	+ 369	967	1,030
10	+ 39·0	38·9	55·1	+ 582	957	1,116
12	+ 20·6	36·4	43·0	+ 373	814	898
14	+ 9·6	45·4	46·4	+ 108	850	857
16	− 4·8	54·6	54·8	− 158	861	875
18	− 4·1	52·1	53·2	− 158	883	891
20	− 11·8	61·6	62·7	− 157	875	889
22	− 15·2	63·5	65·3	− 182	1,082	1,096
Mean	+ 1·2	+ 56·7	56·7	− 125	+ 943	952

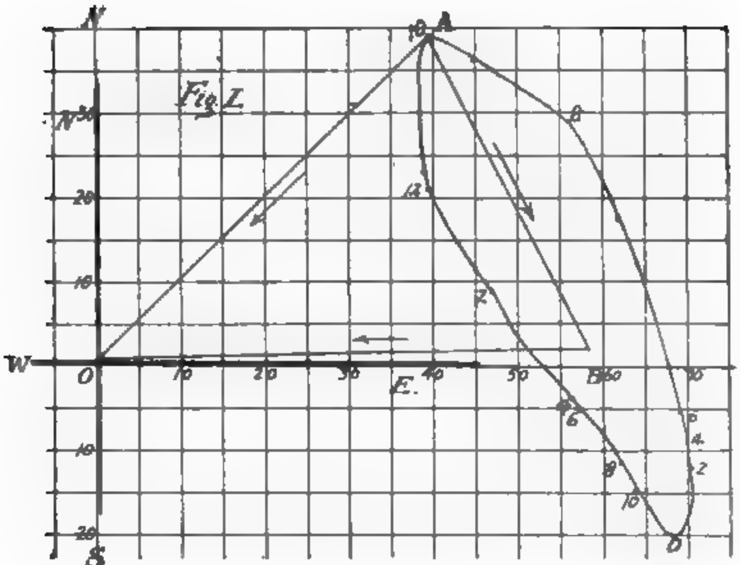


Fig I - Wind Frequency Resultants (Polar Co ordinates)

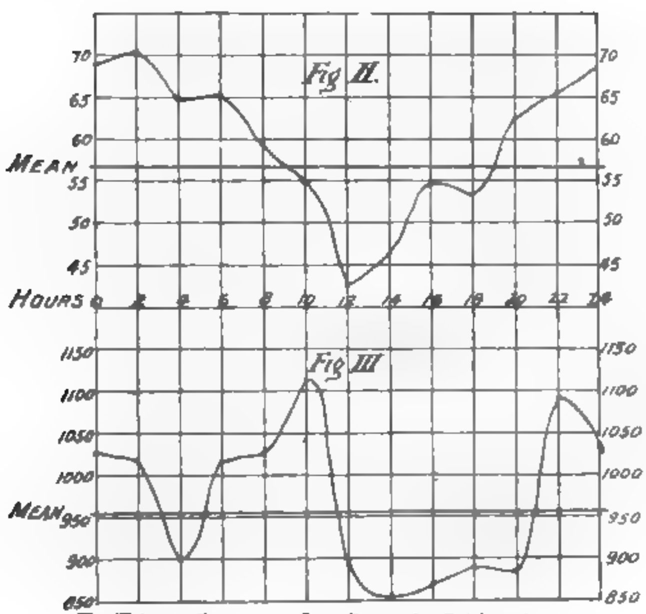


Fig II Wind-Frequency Resultants (V Table A)
Fig III Wind Movement Resultants (V Table A)

From this Table I have constructed the wind frequency curve in polar co-ordinates (the vectors are the resultants of the third column) the two other curves are, the first, the curve of the frequency resultants, the next that of the movement resultants in rectangular co-ordinates.

The frequency resultants all remain between N.E. and E.S.E., the general resultant being nearly due E. This brings well out the fact that we are quite in the trade wind zone. The curve in polar co-ordinates for the wind movement would give similar results, throwing only the resultant about 10 degrees South of East, and bringing the major axis of the ellipse due North. I did not construct it, as the minimum shown at 4 hours on the third curve gives a loop that cannot well be smoothed away.

This result is very different from those got in Johannesburg and in Cape Colony. In Johannesburg the general resultant is N.N.W., in Kimberley it is W.N.W. It compares very much better with the wind system North-East of us, as found in Boroma, near Tete, on the Portuguese Zambesi * where the main wind is from E. to S. E.

The frequency curve constructed as explained above supposes a uniform velocity in the winds in all directions. This is obviously not correct; the two curves in rectangular co-ordinates show the differences introduced by taking into account the variable velocity.

The period of time used in the computation of the wind movement is evidently too short to smooth out the irregularities introduced by errors, and by the variations so capricious a variable as the wind velocity. I am therefore unable to state whether the minimum at 4 hours corresponds to a physical fact or not. Mr. Sutton found also two minima for the wind velocity at Kimberley, and Mr. Innes notes that there was a loop in the curve he gives for the wind movement at Johannesburg. This loop corresponds also to a minimum.

The two curves, however, give a minimum in the afternoon and a maximum at night, and the movement curve has a second maximum at about 10 a.m.

Both the wind variations and the peculiarities we find in the movement curve seem to me to fall in fairly well with the explanation Dechevrens gave for similar but more complicated phenomena at Zikawei (Shanghai). He explains them by something like the Monsoon theory, that is, by the flow of air from the colder to the warmer points. This applied to Bulawayo would work out in the following way. During the day the warmer points are successively E.N. and W. and the wind would veer that way; during night, on account of the wedge shape of South Africa the warmer mass would be that of the ocean South and the wind would veer through South to the East again by sunrise. The force of the wind would depend on

* Cfr 1) The winds of Kimberley. J. R. Sutton. Trans. of the S.A. Phil. Soc., Vol. XI S.1.
2) Transvaal Meteor. Department. Annual Reports. 1904-5. R. T. Innes.
3) The Meteorology of South Africa. Ch. Stewart.
4) Beobachtungen zu Boroma, 1891-2. Von L. Manyhart, S. J., in Publicat des Haynald observ. (Kalocsa) Heft VII.

the difference of temperature between the warmer and colder points and on their distance, therefore the flow would be the strongest in the first hours of the day till the sun being high enough the two points come nearer and get at the same time nearer the same temperature level, when there comes a slowing down of the movement. This will get slower yet by the gradual motion of the warmer points towards the West. In the night, on the contrary, the faster cooling of the land will gradually increase the flow from the South and bring the velocity to a night maximum, till the difference of sea and land temperature will gradually lessen as the night proceeds, and induce a slackening of the wind before sunrise.

If we consider the wind frequency (in polar co-ordinates) we see that the mean wind at each hour can be decomposed into the main resultant B O, which we may consider as a fairly constant trade wind and the variable A B, and if we incline its major axis so as to have it a little East of North instead of West of North we will have what will in all probability represent about the movement curve. We see there that the variable wind varies both in direction and magnitude according to the theory given above, that the hourly resultants increase in the forenoon that they ought to decrease sharply some time about the middle of the day or earlier as the variable component has a different sign from B O, the other component. They should pass through a minimum before sunset and then increase again, but less rapidly than before to pass through a maximum and decrease again but less rapidly than in the afternoon, B O and A B being now of same sign, or even be nearly constant. Now this is certainly very much what happens here. The inrush from the North as the strong North components at 8, 10, 11 hours show is often very marked. The calms fall mostly in the afternoon, the passage of the vane from W. to S. is often replaced by a calm. The nights are rarely quite calm, and as a rule I may say that the afternoon increase of strength in the trade wind which has been observed elsewhere * in the tropics does not appear at all in the records; the afternoons are generally relatively calm. †

The remarks in this paper are, I need not say, only indications of problems that present themselves in the meteorology of Southern Rhodesia. Hard and fast conclusions are premature, and would require a more refined discussion of the available data. One thing, however, may be suggested by the periodic appearance of the various records. I would feel inclined to believe that we are permanently under the influence of the Southern high pressure ridge, or, better, of the South Indian Ocean high pressure area. Small shiftings in this area might account for the small oscillations of the barometer.

* Cf Hann. Lehrbuch der Meteorologie, Vol. I., p. 288 et seq.

† The theory given above would certainly be strengthened if higher up in the tropics we found that the rotation is through the North at one time and through the South at another, following the changes in the Sun's declination. I have no documents at hand to investigate the point.

APPENDIX.

As an illustration of the remarks put down in this paper, I give the two following extracts from the complete tables. One is taken in the rainy season, from December 1 to 19, 1904; the other in the dry season, July 22 to August 28, 1904:—

RAINY SEASON, December 1–19, 1904. Mean December Cloudiness, 6·3.

Date.	Bar.	Temperature.		Rel. Humid.	Rain.	Wind.
		Max. & Min.	Black-bulb.			
Dec. 1, 2 ...	25·559	68·9	140·0	74	·64	Veering
„ 3–6 ...	·687	64·0	138·9	80	·05	E.
„ 7, 8 ...	·642	72·6	155·0	59	0	E. with North
„ 9–12 ...	·630	74·3	160·1	63	1·12	Veering
„ 12 ...	·659	65·0	134·0	88	0	E.
„ 13, 14 ...	·636	65·3	150·0	78	·59	E. with N. and veering
„ 15–19 ...	·660	62·9	115·0	83	·60	E. and E.S.E.

DRY SEASON, July 22–August 28, 1904. Mean August Cloudiness, 1·1. No rain.

Date.	Bar.	Temperature.		Rel. Humid.	Wind.
		Max. & Min.	Black-bulb.		
July 22, 23 ...	25·804	55·9	124·5	64	E.
„ 24, 25 ...	·743	57·1	136·0	50	E. with N. & veering
, 26–Aug. 6 ...	·863	54·4	125·7	55	E.
Aug. 6	·771	60·0	129·5	40	Veering
„ 7–10 ...	·843	60·2	130·0	54	E.
„ 10–14 ...	·791	63·1	133·1	39	Veering
„ 14–18 ...	·831	59·5	130·0	61	E., E.S.E.
„ 18–24 ...	·764	63·7	136·0	53	Veering
„ 24–27 ...	·794	62·9	134·0	47	E.
„ 28	·759	66·5	140·0	34	Veering

7.—VARIABILITY OF TEMPERATURE IN SOUTH AFRICA.

By J. R. Sutton M.A., F.R.Met.S.

It has been pointed out before* that in expressing the terms representing the climate of a place, it is necessary to give, in addition to the elements of maximum and minimum, mean, and range of temperature, what is known as the mean inter-diurnal variability of temperature, that is to say, the mean difference between the temperatures of one day to the next. The present paper is a contribution to this work for South Africa, giving the variability for three typical stations, namely, for Durban, East London, and Kenilworth (Kimberley), of the maximum and minimum temperatures for each month for each station, from ten years' observations, together with the variability of dew-point and relative humidity at Kenilworth at the hours 2 a.m. and 2 p.m.

The mean monthly values of the inter-diurnal variability for Durban are :—

Table 1.—Variability of Temperature at Durban, 1895 to 1904.

	Monthly Means.		Range of Monthly Means.	
	Maximum.	Minimum.	Maximum.	Minimum.
	°	°	° °	° °
Jan.	5·0	2·7	3·2 to 7·9	2·2 to 3·3
Feb.	4·0	2·5	3·1 „ 5·2	2·1 „ 3·1
Mar.	3·8	2·5	3·0 „ 4·5	1·4 „ 3·0
April	3·4	2·5	2·8 „ 5·1	2·0 „ 3.2
May	3·5	2·8	2·7 „ 5·0	2·4 „ 3·4
June	3·2	2·9	2·7 „ 3·9	2·4 „ 3·4
July	3·5	3·0	2·6 „ 4·2	2·3 „ 3·9
Aug.	4·4	3·1	3·6 „ 6·5	2·7 „ 3·8
Sept.	5·8	3·0	3·9 „ 7·7	2·4 „ 3·8
Oct.	5·8	3·6	5·1 „ 7·3	2·7 „ 4·7
Nov.	5·8	3·3	4·1 „ 7·4	2·5 „ 4·2
Dec.	5·4	3·0	3·7 „ 7·1	2·4 „ 3·9
Year	4·5	2·9	2·6 „ 7·9	1·4 „ 4·7

It appears from this that the variability of maximum temperature at Durban is greatest in the early summer, at least at mid-winter. This result is brought about chiefly by the frequent warm and occasional very hot (foehn) winds of September to December. Generally speaking, the temperature of one day at Durban is pretty much like the next; but a hot wind means in nearly every case a sudden rise from the normal maximum one day and an equally rapid fall the next, such pairs of values of great variability making a considerable addition to what would otherwise be the mean variability of the month. It is quite a mistake, though a common one, to

*See *inter alia*, Hann, *Lehrbuch der Met.*, 1901, p 115; Ward, "Suggestions as to a more Rational Climatology," *Report of the Eighth Geographic Congress*, 1905, p. 280.

suppose that these hot winds last for days: as a matter of fact they seldom last more than a few hours, and are usually confined to the daylight hours. They seldom blow during the night, or affect the minimum temperatures to any great extent, although they may on rare occasions recur the second day. The variability of minimum temperature at Durban is least in the autumn and greatest in the spring. Thus the day temperature variability is falling during the first half of the year, while the night temperature variability is rising. The greatest variability of the minimum temperature nearly coincides with that of the maximum; but, as we shall see later, this result is not brought about by the extension of the hot winds into the night, but, on the contrary, is caused by temporary cold winds which, in their turn, have no great influence over the day temperatures. In fact, while the hot winds are essentially cyclonic, the cold winds are as essentially anti-cyclonic, both resembling their prototypes of continental Europe, but differing from them to some extent because of the special geographical conditions of South Africa. Naturally, however, the more frequent the occurrence of cyclonic conditions, the more frequently will anti-cyclonic conditions alternate with them, and therefore, so far, the hot and cold spells may be said to be related to each other. The greatest monthly mean variability of maximum temperature at Durban during the ten years discussed appears in January, 1900, with 7.9°, the least in July, 1901, with 2.6°; the greatest monthly mean variability of minimum appears in October, 1900, with 4.7°, the least in March, 1896, with 1.4°. Large monthly mean values of the maximum temperature variability occur in any of the summer months, while fairly large values of the monthly means of minimum temperature variability occur all through the year.

The mean monthly values of the inter-diurnal variability for East London are:—

TABLE 2.—Variability of Temperature at East London, 1895 to 1904.

	Monthly Means.		Range of Monthly Means.	
	Maximum.	Minimum.	Maximum.	Minimum.
	°	°	° °	° °
January ...	3·3	3·0	2·5 to 4·4	1·9 to 5·1
February ...	3·0	2·4	2·2 „ 3·7	1·7 „ 3·6
March... ...	3·0	2·6	1·9 „ 4·2	2·0 „ 4·0
April	3·3	2·9	2·3 „ 4·0	2·0 „ 4·4
May	5·2	3·5	4·0 „ 6·1	2·7 „ 4·4
June	5·8	3·4	4·0 „ 7·3	2·5 „ 4·1
July	5·5	3·6	3·8 „ 8·5	2·1 „ 5·2
August ...	6·3	3·8	3·6 „ 8·4	2·8 „ 5·6
September ...	4·3	3·6	2·6 „ 6·3	2·7 „ 4·6
October ...	3·6	4·1	2·3 „ 4·6	3·3 „ 5·1
November ...	3·1	3·5	2·3 „ 4·3	2·2 „ 4·6
December ...	2·9	3·0	2·1 „ 3·6	2·2 „ 3·6
Year	4·1	3·3	1·9 „ 8·5	1·7 „ 5·6

At East London the variability of minimum temperature follows the same rule as at Durban, being least in autumn and greatest in spring; the spring values are, however, greater at East London than at Durban, and the average variability for the year is also greater by nearly half a degree. The variability of maximum temperature at East London is, however, of quite a different character from that at Durban, for it is least in summer and greatest in winter. Here, again, we have a result due to the hot winds, which are frequent at East London during the winter season. The average variability of maximum temperature for the year at East London 4.1°, i.e., nearly half a degree less than that of Durban. The greatest monthly value of maximum temperature variability at East London during the ten years 1895-1904 is found in July, 1898, with 8.5°, August, 1897, coming next with 8.4°; the least is in March, 1895, with 1.9°. The greatest monthly value of minimum temperature variability is found in August, 1897, with 5.6°, the least in February, 1897, with 1.7°.

At Kimberley the minimum temperature variability follows the same rule as at Durban and East London, being greatest in October and least in February and March. But the Kimberley maximum

TABLE 3.—Variability of Temperature at Kenilworth (Kimberley), 1896-1905.

	Monthly Means.		Range of Monthly Means.	
	Maximum.	Minimum.	Maximum.	Minimum.
	°	°	° °	° °
Jan.	4·2	3·5	3·1 to 5·1	2·4 to 5·1
Feb.	3·4	3·1	2·6 „ 4·5	2·3 „ 4·1
Mar.	3·8	3·0	2·2 „ 5·1	2·2 „ 4·5
April	3·4	3·2	2·4 „ 4·6	1·6 „ 4·8
May	3·7	3·4	2·0 „ 5·0	2·5 „ 4·1
June	3·8	3·2	1·8 „ 5·7	2·4 „ 4·2
July	4·1	3·4	1·7 „ 5·7	2·7 „ 4·3
Aug.	4·5	4·2	2·6 „ 6·1	2·8 „ 5·4
Sept.	5·3	4·5	3·9 „ 7·1	3·5 „ 5·9
Oct.	5·8	4·8	4·7 „ 8·1	3·7 „ 6·5
Nov.	5·2	4·4	4·1 „ 6·2	3·1 „ 5·7
Dec.	3·9	3·6	2·9 „ 5·0	2·3 „ 4·8
Year	4·3	3·7	1·7 „ 8·1	1·6 „ 6·5

temperature variability differs from both. As at Durban, it is greatest in October; as at East London, it shews a drop in December; whereas its least value comes in April, that is, later than it does at East London, but earlier than it does at Durban. Thus

on the whole it appears that the minimum temperature variability is probably common to the whole country, while the maximum temperature is determined mainly by local conditions. There is a further curious point that the maximum temperature variability is greater than that of the minimum in every month, both at Kimberley and Durban, whereas at East London the minimum values are the greater in the last quarter of the year. In particular, it may be noted that great individual values of the maximum temperature variability do not frequently occur in pairs, on alternate days, at Kimberley, as they do at East London and Durban. The average maximum temperature variability at Kimberley for the year is 4.3°, that for the minimum is 3.7°. Thus the mean variability is greater on the tableland than it is on the coast. The greatest monthly mean maximum temperature variability at Kimberley during the ten years 1896 to 1905 is found in October, 1899, with 8.1°, the least in July, 1905, with 1.7°. The greatest monthly mean minimum temperature variability is found in October, 1904, with 6.5°, the least in April, 1905, with 1.6°. These greatest and least values are not common to the whole country; it by no means follows that a high value of the variability at one station indicates a high value at another at the same time.

The monthly average values of the variability of dew-point and relative humidity, at Kimberley, at 2 a.m. and 2 p.m., are as follows:—

TABLE 4.—Variability of Dew-Point at Kenilworth (Kimberley), 1896 to 1905.

	Monthly Means.		Range of Monthly Means.	
	2 A.M.	2 P.M.	2 A.M.	2 P.M.
	°	°	° °	° °
January ...	5·7	4·4	4·4 to 7·6	3·3 to 6·4
February ...	4·5	3·6	3·2 „ 5·6	2·1 „ 4·9
March... ...	4·3	3·8	2·3 „ 6·1	2·8 „ 5·0
April	3·9	3·5	2·6 „ 5·5	2·2 „ 5·5
May	3·6	3·0	2·8 „ 4·7	2·3 „ 4·6
June	3·4	2·6	2·5 „ 4·4	1·7 „ 3·5
July	3·4	2·5	2·5 „ 4·7	1·6 „ 4·2
August ...	4·1	2·8	2·7 „ 5·4	1·8 „ 4·3
September ...	4·5	3·2	3·0 „ 5·5	2·0 „ 4·5
October ...	6·0	4·1	4·9 „ 7·9	3·2 „ 5·3
November ...	6·0	4·2	4·4 „ 7·5	2·6 „ 5·9
December ...	5·9	4·2	4·3 „ 7·6	3·2 „ 5·7
Year ...	4·6	3·5	2·3 „ 7·9	1·6 „ 6·4

TABLE 5.—Variability of Relative Humidity at Kenilworth (Kimberley), 1896 to 1905.

	Monthly Means.		Range of Monthly Means.	
	2 A.M.	2 P.M.	2 A.M.	2 P.M.
	%	%	% %	% %
January ...	14·7	11·6	12·1 to 19·0	5·1 to 16·7
February ...	12·6	8·8	9·1 „ 15·2	3·2 „ 14·1
March ...	9·8	9·6	6·2 „ 12·6	6·4 „ 13·8
April	10·2	8·2	8·4 „ 13·1	3·6 „ 13·3
May	9·6	6·9	7·6 „ 10·8	4·0 „ 10·5
June	10·0	6·9	7·5 „ 13·2	3·4 „ 12·8
July	9·3	6·5	6·9 „ 11·9	3·2 „ 13·3
August ...	10·5	5·8	6·6 „ 14·9	3·4 „ 9·3
September ...	9·8	6·2	6·7 „ 13·9	3·3 „ 10·3
October ...	12·8	8·2	10·0 „ 14·6	4·4 „ 12·9
November ..	13·7	9·2	9·7 „ 16·5	5·4 „ 14·5
December ...	14·2	10·3	12·6 „ 17·1	6·5 „ 13·1
Year ...	11·4	8·2	6·2 „ 19·0	3·2 „ 16·7

From Tables 4 and 5 it appears that both the absolute and relative humidities change more from day to day in the height of summer than they do in the depth of winter; but that, as distinguished from the temperature variations, the variability of moisture from night to night is considerably greater than that from day to day in respect both to mean and extreme values. This is, to me, a surprising result, considering that the relative humidity has a much wider range by day than by night.

The object of this brief paper is mainly climatological, but it will not, perhaps, be out of place to glance at some of its meteorological aspects.

We have said that the inter-diurnal temperature variability on the coast is much greater than it would be if hot and cold winds did not occur. The hot winds have been dealt with elsewhere.* They are still difficult to account for entirely, but enough is known of them to make it certain that they are associated with a definite type of weather, that they originate on the table-land and blow outwards and downwards, and are quite analogous to the foehn winds of Europe, Greenland, and elsewhere. The cold winds of the coast have not yet been discussed, although they are, from a meterological point of view, at least as interesting as the hot winds.

For the purpose of obtaining a preliminary idea of these cold-weather periods on the coast, I have selected 85 typical cases of low minimum temperature registered in any month during the nine years

*See Stewart, "The Meteorology of South Africa," *Science in South Africa*, 1905, p. 40; Hann, *Met. Zeitschrift*, Jan. 1904, p. 42; Sutton, "The Climate of East London," *Trans. S.A. Phil. Soc.*, Vol. XVI., Part 3.

1896-1904 at East London, and compared them with the simultaneous temperatures at Durban and Kimberley. The following are mean annual results for penthemera, of which the night of a cold wind is the central night, together with the normal means.

TABLE 6.—Mean Annual Minimum Temperature of Cold Spells at East London, compared with the simultaneous Temperatures at Durban and Kimberley.

	First Night.	Second Night.	Third (cold) Night.	Fourth Night.	Fifth Night.	Normal Mean Minimum
East London ...	58°	54°	49°	53°	56°	58°
Durban	63	60	57	57	60	62
Kimberley ...	48	43	42	46	47	50

An examination of these numbers shews that the cold weather is general throughout the country, but that the true epoch of minimum is earliest on the central table-land, and latest at Durban. In fact, the lowest point of the curve of departure from the mean temperature of the five days comes between the second and third day at Kimberley, slightly later than the third day at East London, and between the third and fourth days at Durban. This is a remarkable result, considering that the barometric conditions upon which these low temperatures depend travel from SW. to NE., and are therefore felt earlier at East London than at Kimberley by many hours. If the dependence of the temperatures upon the pressures were absolute we should expect the temperature wave, like the pressure wave, to be felt first at East London, and almost simultaneously, later on, at Durban and Kimberley. It seems to follow, then, that the cold winds in question, like the hot winds, must originate on the tableland, and move downwards to the coast. An analysis of the barometric pressures, which it is unnecessary to give here, supports this view, anti-cyclonic conditions being the rule. For the purpose of investigating the wind movement I have only had access to the anemometer records of East London for the three years 1898-1900; but of the 31 instances of low minimum temperature at East London in those three years 29 occurred with winds blowing off the land, and the other two with wind blowing parallel to the coast, one in December strong from the SW., and the other in October strong from a north-easterly direction. I am inclined to think that in both these exceptional instances there must have been a strong admixture of land wind entering from above. The average velocity of the wind at the time of minimum on the third day in the 31 instances between midnight and 8 a.m. was 19 miles per hour, i.e., about a mile an hour faster than the normal. It is evident from these facts that the cold winds of East London are true *bora* winds, similar in every respect to those of Dalmatia.

A similar investigation for the occasional low minimum temperature periods at Durban gives 83 typical instances, not, as it happens, generally falling on the same day as those in the above comparison for East London. In most of these there is either calm or light wind, and in that respect they differ from the East London cases. The annual averages are :—

TABLE 7.—Mean Annual Minimum Temperature of the Cold Spells at Durban, compared with the simultaneous Temperatures at East London and Kimberley.

	First Night.	Second Night.	Third (cold) Night.	Fourth Night.	Fifth Night.	Normal Mean Minimum
Durban	61°	59°	53°	57°	59°	62°
East London ...	56	54	52	54	57	58
Kimberley ...	47	44	43	46	48	50

Here we see that while the epochs come in the same order as in Table 6, as might have been expected, the low temperature waves of Durban are not so pronounced at East London and Kimberley as the low temperature waves of East London are at Durban and Kimberley. And an examination of the individual instances shews the reason to be that many of the exceptionally low temperatures felt at Durban are not accompanied by any great fall of temperature inland, but, surprisingly enough, are associated in some way with winds from the sea. Nineteen of the 81 cases of low temperature averaged in Table 7 were associated with winds having a component off the sea, that is to say, blowing from anywhere between S. round by E. to ENE. The following are averages for the three stations for the nineteen occasions upon which the wind at 9 a.m. at Durban came in from the sea *

TABLE 8.—Average Minimum Temperatures of the Cold Spells at Durban, with Sea Winds.

	First Night.	Second Night.	Third (cold) Night.	Fourth Night.	Fifth Night.	Normal Mean Minimum
Durban	62°	60°	56°	60°	64°	62°
East London ...	58	57	56	59	62	58
Kimberley ...	51	51	51	55	56	50

* In eighteen out of the nineteen instances the wind was also blowing off the sea at 3 p.m. on the previous day:

The shape of the Durban curve is here nearly the same as in Table 7, where all the cold spells are included, but the epoch is somewhat earlier. Also the average is rather greater, but that is accounted for by the circumstance that cold winds from the sea are not met with during the winter months. The East London and Kimberley comparative values are elevated somewhat for the same reason. While these peculiar conditions are in progress, pressure on the table-land is moderately high, the averages at 8 a.m. at Kenilworth being :—

First Day ...	26·108 inches.		Fourth Day ...	26·129 inches.
Second Day ...	26·169 „		Fifth Day ...	26·116 „
Third Day ...	26·160 „			

and the wind on the table-land shifting from easterly components to westerly. Thus the low temperatures at Durban coincide with the following sides of moderate barometric crests* and the incidence of westerly winds; also the rise of temperature at Kimberley on the fourth and fifth days of the penthemera corresponds to the falling pressure. The average temperature on the table-land for the five days is probably somewhat greater than the mean minimum temperature of the months in which they mostly occur. Now, there is one very remarkable characteristic of these cold sea winds, and that is their dryness. Not one of them carries the quantity of moisture proper to the time of year, the average for them all being fully 15 per cent. short of the mean, and, in spite of their low temperature, they appear to be far from humid. One would scarcely expect a cold, dry wind to blow over an ocean whose water is for its latitude among the warmest in the world. Therefore, because of its dryness, it is probably a re-entering land wind which has somewhere moved outwards, but returned after describing a very short path over the ocean. But how, then, is its temperature to be accounted for? If it originate on the central table-land it must have started as a warm wind, and by dynamic heating in its descent should become still warmer, and thus reach the coast as a warm wind. The cause of its low temperature is therefore still uncertain. In this connection it would be interesting to know whether snow is lying on the crests of the Drakensberg while these cold sea winds are blowing. If not, then the only likely place of their origin seems to be in the main westerly atmospheric drift above, from which they slant downwards and inwards in response to the falling pressure.

* The barometric changes at Durban are appreciably the same as those at Kimberley at these times.

8—ON PREDICTING TIMES OF HIGH WATER AT DURBAN, NATAL.

By R. Fermor Rendell, B.A., F.R.A.S., of the Observatory, Durban, Natal.

[Abstract.]

The Paper contains:—

(*a*) Remarks on the subject, drawing attention to its importance and urgency. The necessity for improved predictions is demonstrated, the only Table hitherto available being frequently more than an hour and a half in error. The writer has devised a method which yields good results.

(*b*) An ephemeris for the whole of the year 1906 is added, giving the times of High Water at Durban, predicted by the new method.

(*c*) A comparison is shown to prove the superiority of the new method. In this comparison the following daily particulars are given in five columns, commencing from September 1st, 1905, and including the latest records to hand at time of writing:—

(1) The predicted times of High Water given in the Natal Directory.

(2) The predicted times calculated by my new method.

(3) The observed times supplied by the Engineer of the Natal Harbour Works.

(4) The discrepancies between the predictions in the Natal Directory and the observations.

(5) The discrepancies between my predictions and the observations.

The results show that the new method is vastly superior to the old. About half of the observed times differ by more than three-quarters of an hour from the old predictions (which are sometimes too early and sometimes too late), while the majority of the new predictions are within a quarter of an hour of the observed times.

For the period of nine months, commencing September 1st, 1905, the *average* discrepancies are 46 minutes and 14 minutes respectively. During this period 495 observed times were investigated.

The following summary indicates the nature of the results:—

	Old Predictions.	New Predictions.
Number of discrepancies over 90 minutes	27	0
,, ,, ,, 45 ,,	245	12
,, ,, not over 15 ,,	68	321

By investigating a longer series of records, the writer hopes to be able to deduce still more accurate values for the quantities in his tables.

9.—THE MANURIAL NEEDS AND RESOURCES OF THE TRANSVAAL.

By Herbert Ingle, B.Sc., F.C.S., F.I.C.
Chief Chemist, Transvaal Department of Agriculture.

Though at present the economic importance of the Transvaal depends mainly upon its mineral resources, there can be no doubt of the vital interest attached to the agricultural possibilities of the country if it is to become the permanent home of the colonist.

A factor of the utmost importance in determining these possibilities is the character and composition of the soil, for though climate, rainfall, water supply, possibility of finding a market for produce, and other circumstances, to a great extent determine the progress of agriculture as a business, these become merely insignificant considerations if the soil be not productive.

The chemical composition of the soil, though by no means the only item of importance in assessing its productiveness, is certainly a great factor in gauging its potential fertility. Unless the constituents of plant food are present in the soil in sufficient quantity, no combination of favourable circumstances as to temperature, water supply, and other features, will yield good crops.

Until recently, but few analyses of Transvaal soils had been made. The few that were available indicated that, compared with European soils, those of the Transvaal were poor in most of the important constituents of plant food, and that, judged by the experience of ordinary temperate climates, they were in urgent need of manures.

During the past three years, analyses of about 160 samples of soil from various parts of the Colony have been made in the Chemical Laboratories of the Transvaal Department of Agriculture, so that we are now in a position to speak with some degree of confidence as to the general character of our Transvaal soils, so far, at least, as their chemical composition is concerned.

In a tract of country so extensive as the Transvaal, we find, as is to be expected, considerable differences in composition among the samples, but, though here and there are to be found patches of soil rich in most manurial ingredients, the greater number of samples indicate that the soil, in general, is poor in organic nitrogenous matter, phosphates, and lime. Potash compounds, with some few exceptions, are generally sufficiently abundant. Again, speaking from the experience of European countries, most of our Transvaal soils would appear to need additions of combined nitrogen, phosphates and lime, in order to possess average fertility.

But to judge soils in tropical countries from the standpoint of the experience obtained in temperate and less sunny climates is not fair. It is found in actual practice that a soil of extreme poverty, compared with average English soil, will often, in this country, yield quite respectable crops.

This is the experience in other parts of the world, e.g., Assam, where the tea soils of great apparent poverty, nevertheless yield good crops. Several factors, no doubt, are influential in bringing this

about. As I have stated elsewhere, these are probably the following :—

1. The favouring influences of brilliant sunshine and high temperature upon plant growth.

2. The greater rapidity with which chemical changes probably occur in the soil. This would enable plants to obtain a sufficiency of food from a soil which, under circumstances less favourable to chemical changes, might be too poor in fertilising constituents. Organic matter in our soils very quickly decays, and no doubt the changes which render potash and phosphoric acid available, also proceed more rapidly than in cooler climates.

3. Most of our soils are of open texture and considerable depth, thus allowing of abundant root development.

4. Our rain is richer in combined nitrogen than that of cooler countries, and the rainfall being confined to the growing season, brings almost all its nitric acid and ammonia into contact with the feeding roots. In Pretoria, the total amount of combined nitrogen brought down in the rain amounts to about 7.5 lbs. per acre per annum, as against about half that quantity at Rothamsted, and, whereas in England this addition of nitrogen is distributed almost uniformly over the whole year, and a large portion is thus wasted, in this country it is confined to the summer, when the crops are in a condition to assimilate it. The absence of winter rains is also important in lessening the loss of nitrates from the soil by drainage. In Europe quite a large quantity of nitrogen is washed out of the soil into the drains, especially in autumn and winter, when the land is, for the most part, clear of crops. In this Colony no loss of this kind occurs, as in most districts the winter is absolutely rainless.

5. The dryness and low pressure of our atmosphere leads to rapid evaporation both from the leaves of plants and from the surface of the soil. The rapid transpiration of water from the leaves enables the plant to use up large quantities of the very dilute solution of its food existent in the soil, and thus to obtain a sufficiency from the soil water even when the latter is so weak that it would, in a damper climate, be incapable of providing the needed constituents in sufficient quantity. The evaporation of moisture from the surface of the soil brings up water from below, carrying with it small quantities of dissolved matter from the soil, and concentrates this dilute solution in the upper layers, so as to render it more capable of supplying the roots with plant food. The latter process sometimes goes on to an injurious extent, and sets up a "brak" condition of the surface soil.

But to return to the character of Transvaal soils as revealed by our analyses.

In a paper read last year before the Chemical Section of the British Association for the Advancement of Science at Johannesburg, I gave in detail the results of the analyses of nearly 100 samples of soils collected from various places in the Colony, and discussed at some length the general manurial treatment necessary to enhance their fertility. Since then some 60 to 70 additional soils have been

examined in our laboratories. I do not propose to give a long array of figures, but will be content to deal with averages as far as possible. In last year's paper, above referred to, will be found details of the methods employed in the analyses, and a discussion of the deductions which may be drawn from the various determinations.

It must suffice on the present occasion to point out that although plants require from the soil a large number of substances, the actual fertility generally depends upon the soil's capability of supplying a sufficiency of four materials, viz., combined nitrogen, potash compounds, phosphates, and lime. Other constituents of plants, e.g., sulphur, chlorides, iron, magnesia, etc., though indispensable, are so widely distributed that it is rare to find soils lacking in them.

For the present, then, only the four first-mentioned constituents will be considered.

COMBINED NITROGEN.

In most soils this is present almost entirely in the form of complex organic compounds, resulting from the decay of vegetable or animal matter. The organic matter, in addition to yielding supplies of nitrogen, has an important influence on the water-holding capacity of the soil.

In this state, nitrogen is not available to plants, but becomes so by processes of decomposition, resulting in the formation of ammonium compounds, nitrites, and, lastly, nitrates. It is in this form that practically all the nitrogen which the plants require is assimilated. The successive changes which lead to the formation of nitrates from complex organic nitrogenous compounds are known as nitrification, and are accomplished under the influence of at least three species of micro-organisms. In order, therefore, for a soil to be well adapted for supplying nitrogen to plants, it is necessary for it to possess a sufficient store of organic, nitrogenous matter, suitable micro-organisms, and the necessary conditions for their activity. Among the latter, some of the most important are sufficient moisture, the presence of some basic material, suitable for the formation of nitrates, and a moderately high temperature. The first and last of these are mainly dependent upon climatic conditions, the only modification which is practicable for man to introduce is by means of irrigation. The basic material most suited for the purpose is carbonate of lime, and the process of nitrification leads to a consumption of this substance.

Most of our Transvaal soils are low in lime, and the process of nitrification is probably limited in many cases by the deficiency of basic material. On the other hand, other conditions for rapid nitrification, e.g., high temperature, porosity, and, in the summer, moisture, are favourable in this country.

The amount of combined nitrogen in most of our soils is very low, compared with ordinary English soils. There are, of course, many exceptions, for soils from marshes, or "vleis," are often rich in organic matter, and also in nitrogen.

In an ordinary English arable soil one usually finds about 0.2 to 0.3 per cent. of nitrogen. The average of the 168 samples of Transvaal soils, examined in our Laboratories, gives 0.126 per cent. But this alone would be misleading, for, leaving out 17 soils which contained more than 0.20 per cent., the remaining 151 soils only contained an average of 0.093 per cent. of nitrogen. It is not infrequent to find 0.05, 0.03, or even 0.02 per cent. of nitrogen in samples of our soils. Soils containing so little nitrogen as, say, 0.1 per cent., would be regarded in England as hopeless unless heavily manured with nitrogenous material, but yet many such soils in this Colony are found to yield fair crops. It is probable that this is mainly due to greater rapidity of circulation of nitrogen in the warmer climate.

POTASH.

In this constituent our soils are, as a rule, fairly rich, the average amount in all the 168 samples being about 0.23 per cent. Few samples are below 0.10 per cent., while in a few cases about 1.0 per cent. was found. It is probably rare that potash manures are needed on our Transvaal soils, though a few samples have yielded results indicating that they would be benefited by additions of potash. In about 50 samples out of the 168 examined, the proportion of potash extracted by treatment with 1 per cent. solution of citric acid was less than 0.005 per cent., which has been proposed for English soils as the limit below which potash manures are probably needed.

PHOSPHATES.

These substances are markedly deficient in most of our soils. In England the proportion of phosphoric acid present varies greatly, but is usually about 0.10 or 0.15 per cent. In our Transvaal soils the amount rarely reaches 0.1 per cent., and is often less than 0.04, or even 0.03 per cent. The mean of all the 168 samples gives 0.06 per cent. of phosphoric acid, but this includes some exceptionally rich specimens, containing from 0.15 to 0.20 per cent. of phosphoric acid. Phosphates are as much needed on most of our soils as nitrogen and lime. In only 32 out of the whole 168 samples did the amount of "available" phosphoric acid, i.e., the quantity extracted by 7 days' treatment with 1 per cent. solution of citric acid, exceed 0.01 per cent., which, in England, is taken as the limit, below which phosphatic manuring is considered advisable.

LIME.

The presence of lime in the form of carbonate is of great importance, not only for the effect upon nitrification already alluded to, but also for the important action it has upon the physical properties of the soil. Soils containing clay in sufficient quantity to be "heavy" and tenacious, become much more friable and porous if

carbonate of lime be present. The amount of lime present in the samples examined has varied greatly from the merest trace to as high as 30 per cent. in some limestone soils. But, except on limestone outcrops, the soils are, as a rule, very low in this constituent. The average of all the 168 samples gives 0.81 per cent. of lime, but, as already stated, this includes several samples, consisting largely of powdered limestone. Taking 0.25 as a standard, there were 70 samples containing more than this, and 98 containing less.

The average of the 70 is 1.86, that of the 98 only 0.093 per cent. In many cases less than 0.05 per cent. of total lime was found. There can be little doubt that the application of lime in small dressings to many of our soils would be attended with a great increase in fertility.

The needs of our Transvaal soils, generally, then, are organic matter (humus), combined nitrogen, phosphates, and lime. It is of interest and importance to consider how these needs may be supplied by the natural resources of the country. Before doing so, however, it will be advisable to briefly discuss the form in which these constituents may be applied to the soil. Organic matter, present in the very complex and indefinite form known as humus, is in the great majority of our soils, very deficient in amount. Its amount may be increased by the addition of bulky animal or vegetable matter. Stable or kraal manure, if available, is undoubtedly one of the cheapest and best manures for this purpose, especially as it also supplies small quantities of all the constituents needed by a soil. But in this Colony the quantity available in any one locality is very limited, and the cost of transport is too high to allow of its being brought from a distance. The amount of organic matter in such substances as guano and bats' guano is too small to allow of these substances having much influence directly upon the amount of humus in the soil, though they have great value as true manures. The organic matter may, however, be very greatly increased by the practice of green manuring. By growing any crop on land and plowing it in, before it seeds, a large addition of carbonaceous matter obtained by the crop from the air is added to the soil, and may greatly improve it by increasing its water-retaining powers, and in other ways.

If the crop chosen be a leguminous one, an additional advantage is gained by the addition to the soil of the nitrogenous matter contained in the crop, which has been obtained mainly from the nitrogen of the air. In many of our soils, the micro-organisms necessary to effect this absorption of free nitrogen in the root tubercles of many *leguminosæ* are already present, but, in any case, their presence may be insured by inoculation of the seed before sowing, with cultures of the specific organisms.

This is a plan which might with great advantage be adopted on many of our soils, but it must be remembered that the other necessary constituents, phosphates, potash, and lime, must already be present in sufficient amount to allow of a luxurious growth of the leguminous crops. or the advantage gained will be small.

NITROGEN.

may be applied in the form of complex organic compounds, such as are present in animal and vegetable matter, as already described; in the form of ammonium compounds, or, lastly, in the form of nitrates. Organic nitrogenous substances are contained in kraal manure, guano, various oil cakes, human excreta, animal matter of all kinds, blood, offal from butchers, bones, and similar refuse. Before such substances can be utilised by plants, it is necessary, as already stated, that they undergo the process of nitrification, and therefore that the soil contain some carbonate of lime. Ammonium salts, e.g., sulphate of ammonia, have also to be nitrified before they can be absorbed into the plant. Moreover, the acid of the ammonium compound has to be combined with some base from the soil, so that with these manures, the presence of much carbonate of lime in the soil is essential.

Nitrates, on the other hand, are directly assimilated, and have not to undergo any previous change. They, however, are not retained by the soil, as are ammonium salts and most other manures, and therefore should not be applied until the plant is well rooted and can absorb them.

PHOSPHORIC ACID.

This may be applied in three forms.

1. As tricalcium phosphate, e.g., in bones.
2. As acid calcium phosphate, e.g., in superphosphate.
3. As tetra-calcium phosphate, e.g., in basic slag.

The first has the disadvantage of being insoluble in water, therefore difficult to distribute through the soil. It is slow in its action, as it is only absorbed by the plant after it has come into solution in the soil water by action of carbonic and other acids produced by chemical changes in the soil or plant. The second form of phosphatic manure has the advantage of being easily soluble in water, and therefore quickly distributes itself throughout the soil. It is, however, soon converted by the calcium carbonate into the first form. Nevertheless it is readily available to the plant, because of its fine state of sub-division and good distribution throughout the soil. This form of phosphatic manure can only be used successfully on soils containing a fair amount of carbonate of lime. The third form of phosphatic manure, though insoluble in water, is much more readily soluble in saline solution than the first, and, if applied in a sufficiently fine state of sub-division, is rapidly assimilated by plants. Basic slag contains free lime, in addition to its tetra-calcium phosphate, and is especially suited to soils poor in lime.

It gives excellent results on soils rich in organic matter, probably because the free lime in it promotes nitrification, while the vegetable acids resulting from the decay of the organic matter aid in the solution of the phosphoric acid.

LIME.

This, which is so much needed in most of our soils, is actually useful in the form of carbonate. The best effect, however, is produced by the application of the oxide or hydroxide (quick lime or slaked lime), because these substances, being soluble in the water of the soil, are disseminated far more thoroughly than would be possible with even the most finely-divided carbonate of lime. After addition to the soil they are gradually converted by absorption of carbon dioxide into carbonate, but not until their distribution by virtue of their solubility in water has been effected. So long as the lime remains in the caustic or alkaline state, the soil is not fitted for the growth of plants. Hence lime containing much magnesia (which absorbs carbon dioxide much more slowly than lime), such as results from burning magnesian limestone, is not suited for agricultural purposes.

THE MANURIAL RESOURCES OF THE COLONY.

1.—COMBINED NITROGEN.

A. *Nitrogenous Organic Matter.* As sources of this valuable substance the Colony has, like all inhabited countries, the excrements of domestic animals and of the human inhabitants, but the quantity of this material is limited, and at present inadequate to supply the needs of the soil. Kraal manure, bucket refuse from towns, waste portions of animal carcasses, and such refuse, should all be carefully utilised on the land, as they contain valuable quantities of combined nitrogen, as well as phosphates, potash and lime. Also valuable for the same reasons are the enormous cave deposits found in many limestone districts. Many of these deposits have been examined in our laboratories, and, while they have proved to be extremely variable in composition, there is no doubt that they form a valuable manurial asset. Some of the more recent deposits are very rich in nitrogen. Specimens containing as much as 9.7 per cent. of nitrogen have come under our notice, but much of the material found in the caves consists largely of fine silt, containing but little fertilising matter. Bones of animals, and excreta of wolves and other animals occur in many of the caves, and thus increase the phosphatic value of the deposits considerably and the nitrogenous value slightly.

The excrement of vultures, which occurs in considerable quantities near the nesting-places of the birds, is exceedingly rich in nitrogen. A specimen examined in our laboratories, obtained from the Orange River Colony, was found to contain about 25 per cent. of nitrogen, and to have a value, when compared with the cost of artificial manures at the coast, of about £17 per ton.

Another product which might be utilised as a nitrogenous manure in this Colony is the locust. In the Transvaal during the past winter locusts have been only too abundant, and I would certainly recommend that farmers should endeavour to utilise them, especially as this would tend to diminish their number. Though they could probably

be more profitably employed as food for pigs, poultry, etc., they have considerable value as manure. If they were collected in sacks by natives—easily done at night or in the early morning on their roosting-places—killed by being dipped into boiling water, and then dried in the sun, they could be ground in any ordinary mill. The powder thus formed, if not utilised as food, would form an exceedingly valuable manure. The product from the adult brown locust was examined recently by the writer, and was found to contain 9.5 per cent. of nitrogen, 0.28 per cent. of lime, and 1.59 per cent. of phosphoric acid. Compared with prices of artificial manures at the coast, ground locusts would thus have a fertilising value of about £7 10/- per ton.

It is true that they would probably be somewhat slow in their action as a manure, but they would undoubtedly contribute largely to the fertility of the soil to which they were applied, while the advantage to the country at large resulting from their destruction during the breeding season would be undoubted.

Still another product, possessing value as a local source of nitrogen (and other manurial substances) is the material composing ant-heaps. These are abundant enough in many districts, and when crushed afford a fine-grained soil which is much richer in nitrogen than the soil of the surrounding veld, and could be used with advantage for seed-beds for nurseries and gardens. This plan has been practised by several farmers and others in the Transvaal with great success, and it might be much more largely adopted.

A specimen of such material from an ant-heap, and another of the soil taken three feet away, near Christiana, were examined by the writer, with the following results :—

	Ant heap.	Veld soil.
Stones retained by 3 mm sieve	none	8.66
Moisture	3.28	1.98
*Loss on ignition (organic matters, etc.)	13.03	4.14
Insoluble matter (sand, etc.)	74.59	82.86
Iron oxide and alumina	8.79	9.89
Lime	0.30	0.12
Magnesia	0.40	0.18
Potash	0.39	0.25
Phosphoric acid	0.06	0.06
	100.84	99.48
*Containing nitrogen	0.343	0.080
"Available" Potash	0.0482	0.0121
,, Phosphoric acid	0.0102	0.0017

The superiority of the ant-heap material in organic matter, nitrogen, and "available" potash and phosphoric acid over the veld soil shows that it might be used with great advantage on poor soils, though, of course, it is not worth transporting any distance. Probably

their fine texture and somewhat coherent character would render ant-heaps too close and impervious to yield a good soil by themselves, but by mixing them with a sandy soil this could readily be remedied.

B. *Ammonium Salts.* These, which are in Europe produced as bye-products in the distillation of coal and shale, are not made in any quantity here. Very little coal is used for gas-making, so that the amount of ammonium salts produced in the Colony must be insignificant. Moreover, in the case of many of our soils, deficient as they are in lime, these substances would not be very suitable unless a dressing of lime were previously applied.

C. *Nitrates.* Unfortunately few authentic cases of the occurence of nitrate deposits are known in the Transvaal. I have had several saline deposits sent from various localities for examination, in the hope that they would be found to consist largely of nitrate of soda or potash, but none have been found to be of any value. A deposit was reported to have been discovered in the Zoutpansberg about a year ago, but I have not been able to obtain any information concerning it. I am told that many of the older farmers in the Colony speak of "saltpetre" occurring in crystals on stones in the neighbourhood of pans, but I have not been able to ascertain whether the substance so called is ever really saltpetre, i.e., potassium nitrate. If such deposits do occur, it is very important, since nitrate of potash or soda would be of immense service in agriculture, provided its price were reasonable. The cost of the imported South American product is very high in this country on account of freight and transport charges.

At present, unless the farmer is willing to pay the very high prices for imported nitrate of soda or sulphate of ammonia, he must chiefly depend for nitrogenous manuring upon organic matter, kraal and stable manure, bucket refuse, carcasses of animals, bats' guano and kindred substances, or adopt the plan of enriching the soil by the growth of leguminous crops and so obtaining nitrogen from the air.

2.—PHOSPHORIC ACID.

A. *Bones.* There are considerable quantities of bones available in the Colony. In additon to those of animals slaughtered for food, there are the bones and bodies of those which die from disease; unfortunately, these have been only too numerous in late years. Then, too, large quantities of bones occur scattered over the veld as relics of the horses, mules, and oxen which died during the war.

Bones, when reduced to fine powder, form a valuable though somewhat slow-acting manure, and might with advantage be largely employed in agriculture here.

The carcasses of animals which die from disease might, as a preventative of the spread of contagion, be burnt in a suitable furnace, and the residue would form a valuable phosphatic manure. A sample of such "ash" from the crematorium at the Veterinary

Station at Daspoort, was recently examined in our laboratories, and gave the following results :—

Moisture	1.39
*Loss on ignition	13.09
Insoluble matter (sand, etc.)	13.78
Iron oxide	5.17
Lime	35.23
Magnesia	0.66
Potash	1.48
†Phosphoric acid	28.16
Alumina, soda, etc.	1.04
	100.00

*Containing carbon dioxide	1.97 per cent.
,, nitrogen	1.27 ,, ,,
†Corresponding to phosphate of lime	61.48 ,, ,,

This substance, compared with the price of manures at the coast, would be worth about £7 9/- per ton.

B. *Other phosphatic manures.* Unfortunately, deposits of true mineral phosphates are rare in the Colony, and though several specimens of minerals suspected to consist largely of phosphate of lime have been received from various correspondents, none have proved to be of any value.

However, in many limestone districts, caves—really old underground water courses—exist and in many of these deposits containing the excreta of wild animals, wolves, jackals, and others, bones of these animals and their prey, and in some instances, immense quantities of the excrement of bats, mingled with fine silt, occur. These cave deposits always contain some, and often much, phosphoric acid, in addition to nitrogen, potash, and lime. Such deposits are certainly useful as manures.

Large numbers of samples of this material have been examined in the laboratories, and the results show, as might be expected, great variability.

I append a table giving the proportion of the chief manurial constituents in seven samples, which may be taken as typical of such cave deposits :—

	1.	2.	3.	4.	5.	6.	7.
Phosphoric acid	3.81	2.82	1.71	26.55	1.58	2.26	7.4
Potash	1.29	0.78	0.21	0.05	1.14	0.19	—
Nitrogen	9.7	1.50	0.19	0.32	1.56	2.52	6.2
Lime	—	—	0.37	33.14	14.54	7.28	0.8

1 was a fresh bulky deposit, consisting entirely of bats' dung from Chune's Poort range in the Zoutpansberg.

2 was from caves near Potchefstroom (bats' guano and silt).

3 was from the large cavern at Wonderfontein (bats' guano and silt).

4 said to consist mainly of wolves' dung (Wonderfontein).
5 contained many bones (Wonderfontein).
6 was a recent deposit, bats' dung and silt (Wonderfontein).
7 a recent deposit from Elandsfontein caves, near Pretoria.

In certain districts it is the custom to employ dried sheep's dung as fuel on the farms. Sheep's kraal manure, used as fuel under the name of "Mest," was found by Lewis in 1899 to contain (average of 11 samples):—

Nitrogen	1.31
Potash	2.84
Phosphoric acid	1.26

While E. H. Croghan, in a paper read last year before the British Association at Johannesburg, found 25 samples from Cape Colony and the Orange River Colony contained:—

Nitrogen	0.55 to 1.68,	mean	1.22	per	cent.
Potash	1.23 to 5.86	,,	3.85	,,	,,
Phosphoric acid	0.38 to 1.28	,,	0.78	,,	,,

the ash left when "mest" is burnt is free from nitrogen, but much richer in potash and phosphoric acid.

Lewis found, as a mean of 3 samples:—

Potash	7.60	per	cent.
Phosphoric acid	2.59	,,	,,

While Croghan, in 25 samples, found quantities ranging from:—

Potash	3.74 to 18.57	per	cent
Phosphoric acid	1.20 to 3.50	,,	,,

In certain parts of the Transvaal are old cattle kraals, used by the natives before the incursions of white men. The deposits overlying these kraals are almost devoid of nitrogen, but still retain considerable quantities of potash and phosphoric acid. A specimen of such deposit, from near Rustenburg, from a kraal said to have been used about a hundred years ago, was found to contain:—

Potash	1.52	per	cent.
Phosphoric acid	2.00	,,	,,

This deposit has been largely used by the local farmers with successful results during the last 7 or 8 years, when kraal manure has been scarce.

Another remarkable source of phosphoric acid has come under my notice—the ash of certain Transvaal coals. In a specimen of coal ash from one of the Witbank Collieries I found 5.5 per cent. of phosphorus pentoxide.

Though doubtless the phosphoric acid would be largely present as phosphate of iron, and therefore not readily available, it might form a cheap and useful manure.

The night soil of some of the compounds on the Rand is treated so as to render it odourless by heat. The so-called " ash " left was found to contain :—

Phosphoric acid	13.9 per cent.
Potash	7.3 ,, ,,
Nitrogen	1.7 ,, ,,

If the product can be produced in large quantities, and equal to the sample, it should find a ready sale as a fertiliser.

From the above account it will be seen that the natural sources of phosphates in this Colony are limited, and in many instances it may be necessary to purchase imported materials. Superphosphates are well suited for such of our soils as contain, say, one per cent. or more of lime as carbonate, but with the great majority of our soils, poor as they are in lime, basic slag or " Thomas phosphate " will probably be the best form of phosphatic manure.

3.—LIME.

Fortunately, of this important substance, the Colony has large natural resources. Quantities of limestones, some of great purity, exist in many districts, and though I believe that it is true that a large proportion of the lime commerciably obtainable is of poor quality, being badly burnt and containing much insoluble matter and magnesia, this could be easily remedied by proper management, and the choice of suitable limestone.

We have examined many specimens of limestones, and among them were some of excellent quality, capable, if properly burnt, of yielding lime admirably suited for agricultural purposes.

As typical examples of such pure limestones, though it is, perhaps, more correct to describe some of them as calcite, but of which large deposits are said to be available, I may quote the following analyses :—

	1.	2.	3.	4
Insoluble matter	0.2	0.2	0.2	7.89
Iron oxide and alumina	0.2	0.2	0.1	0.67
Lime	55.4	55.8	55.2	49.93
Magnesia	0.9	0.2	0.9	0.52
Carbon dioxide	43.0	43.3	43.2	39.80
Moisture	0.2	0.2	0.2	1.08
	99.9	99.9	99.8	99.89

As examples of the commercial lime obtainable, the following may be cited :—

	"Blue lime."	"Blue lime."	Good white lime.
Total lime	55.85	52.44	92.94
Magnesia	17.87	17.25	traces
Loss on ignition	15.68	18.35	5.50

In some districts limestones do not occur, and I have had correspondence with farmers who were anxious to procure lime for agricultural purposes locally, so as to avoid the cost of transport from a distance. Several substances suspected to be rich in lime have been sent to me, but on examination these minerals have been found to be almost free from that constituent.

The ashes of certain trees have been found to be very rich in lime, and might be used for agricultural purposes when available. Thus a tree from Mozambique was found to yield about 6 per cent. of ash, of which about two-thirds consisted of lime. Another sample, the ash of a tree known as "Mopani," growing in the Tati Concessions country, was found to contain over 55 per cent. of lime, a considerable portion of which existed as carbonate.

4.—POTASH.

As already stated, it is on comparatively few of our soils that potash manures are required.

Probably wood ashes are the most readily available natural source of potash, especially the ash of twigs, brushwood, etc.

Should imported manures be used, preference should be given to sulphate of potash. On no account is it advisable to use the lower-priced Kainite, which is open to the objections of involving a much greater cost in transport for the same quantity of potash, and to being contaminated with large quantities of saline matter, which is not only useless, but may prove very harmful.

In conclusion, I would emphasise the importance of utilising as fully as possible the natural manurial resources of the country, and thus avoiding the expense which is involved in the purchase of imported manures. Indeed, so high are the prices of the latter, when the cost of transport is included, that it is often a matter of difficulty to know whether one is justified in recommending their use, and whether the undoubted increase in yield which would follow their application would pay for their cost.

Greater attention should be paid by the farmers to the preservation and restoration to the land, of all the waste products of the farm, the use of green manuring, and all means by which the much-needed combined nitrogen, phosphates, and lime may be conveyed to the soil.

10.—ON THE OBSERVATION OF EARTHQUAKES AND OTHER EARTH MOVEMENTS.

By John Milne, F.R.S.

At the present time the greatest seismic activity in the African Continent is to be found in the high lands of Algeria and in the vicinity of the Great Lakes, and Abyssinia. If from the former of these districts we travel Eastwards in the direction of Tunis, or Westwards through Morocco and turn Southwards down the Western side of the Continent, the activity rapidly decreases. A similar decrement is met with if from the central region we go Northwards down the Nile Valley or Southwards towards Cape Colony. Not only is the frequency small, but the shocks themselves are insignificant. They are local in character, and probably represent slight adjustments on lines of existing faults. For ten years at least Africa has not produced a single world-shaking earthquake, the inference from which is that during this period no large fault has been created. If, however, we regard the African Continent as a mass which extends Eastwards to the floor of the Indian Ocean, we find that the sites of several megaseismic efforts have been traced to this submerged frontier. From the changes which have taken place in soundings after a large earthquake which has originated beneath a sea or ocean, but more particularly from measurements made on land, when it has been found that valleys have been contracted, and the lengths of trigonometrical lines have been altered and from other observations, the conclusion arrived at is that a world-shaking earthquake originates from the faulting, shattering, and the displacement of an area only to be measured by many thousands of square miles. If we had a knowledge of the depth to which the faulting extends, a cubic measurement might be made of the magnitude of these molar displacements. Inasmuch as they transmit sufficient energy through the crust of our earth to create movements which may be recorded at the antipodes of their origin, it seems probable that the displacement downwards extends to a considerable depth. If we regard the crust of our world as a layer of materials which conveys elastic vibrations at about the same rate as they are conveyed by the rocks we see, then seismological investigations indicate that this covering is less than 30 miles in thickness. In relation to the area which is displaced, fracturing to this depth, or, at least, to a large fraction of the same, might be compared to the formation of the tiny cracks we sometimes see in the varnish covering an ordinary globe. The origins of the displacements along the line of the Mozambique synclinal have apparently been too far from the African coast for the resultant vibrations to be felt, but they have been recorded in very distant countries. At the present time in Africa the British Association type of seismograph, which is not adapted to record local earthquakes which can be felt, but only to record unfelt teleseismic motion, is only to be found at Cape Town and Cairo. Forty other similar instruments are installed in Europe, Asia, America, and Australia. Capt. H. E. Lyons, R.E., of the Egyptian Survey Department, now proposes to establish observing stations at Khartoum and Lake Victoria. The

object of the latter installation is not simply to make a register of world-shaking earthquakes, but to obtain a continuous record of changes in level. The water of Lake Victoria fluctuates in its height, and it is suspected that this may possibly be due to rock folding. If this is the case, then a seismograph, which can be adjusted to record small changes in level, may possibly yield information connected with the water supply of Egypt. Between Victoria and Cape Town there is a stretch of some 2,000 miles, in which, if two or more stations were established, records would be obtained of immense value to the seismic survey of the world which is now in progress.

Not only would they be of value as a means of extending our knowledge respecting the nature of the interior of the planet on which we live, but from time to time seismograms would yield information of immediate practical value to South African communities. Certain colonies have established seismographs because they furnish information as to the cause of a certain class of cable interruption. Cables may cease to work in consequence of the operations of an enemy, in consequence of sub-oceanic seismic disturbances, and for other reasons. A community that can be assured of the reason why its communications with distant places have suddenly ceased, should certainly be less liable to anxiety and alarm than one without similar information.

For the East Coast of Africa in 12 years I find that out of 19 cable interruptions 11 of these have corresponded with unfelt earthquakes which were recorded at many stations in different parts of the world.

It cannot be said definitely that these earthquakes were the cause of the interruptions, but the fact that both occurred on the same days, and that it has so frequently happened that cables have been parted by sub-oceanic convulsions, makes it appear likely that in certain instances, at least, we may be dealing with causes and their effects.

On Jan. 31st of this year an earthquake off the Coast of Columbia, the effects of which found responses in the W. Indies, was responsible for the parting of 8 or 9 cables.

When one or two more earthquake observing stations have been established in Africa, the origins of these sub-oceanic catastrophes will be localized, and their relationship to the cable interruptions will be better understood.

Seismographs have been established at Potsdam and at several magnetic observatories in the United States, mainly because the records they yield throw light upon perturbations noted in certain magnetograms. At other observatories records of unfelt movements of the ground have explained accelerations and retardations in timekeepers, sudden displacements on barograms, and unusual movements of electrometers, the assayers' balance, and other instruments. In addition to changes of level, which are only appreciable after long intervals of time, a horizontal pendulum readily records changes which take place with comparative rapidity. Diurnal changes in level, which are chiefly noticeable in fine weather, have been recorded

at a depth of 19 feet in sandstone. On the opposite sides of two valleys where instruments have been established, it is found that these daily movements take place simultaneously, but in opposite directions. During the day we may picture a valley opening, and at night as closing.

Bearing in mind that these diurnal movements are only marked on bright, sunny days, and are practically absent in dull, wet weather, we may seek for their explanation either as a general expansion of the ground under the influence of sun heat, or to a diurnal loading and unloading of a valley bottom relatively to that which takes place upon its sides.

The fact that these deflections of the pendulum may be observed in cellars and chambers excavated in rock where temperature is practically constant, precludes the idea that they are due to any local heating of the foundation on which the instrument may be installed. It, however, does not preclude the idea that there may be a general superficial warping of a district as an effect of solar radiation. It is, however, remarkable that this action should extend to the depths at which it has been observed.

That valley beds convey more load at night than they do during the day is suggested by various observations. Engineers have shewn that under normal conditions certain streams carry the most water at night-time. This is also true of certain drains and wells. The causes leading to these conditions may be various. A nocturnal increase in the flow of sub-surface water may be attributed to the expansion of air in soil by the slowly-descending heat of the previous day, which forces interstriaal water into channels of easiest flow.

Another explanation rests on the fact that during the day evaporation and vegetable transpiration are at a maximum, whereby the flow of sub-surface water is diminished.

At night, with the cessation of these activities, the flow is relatively increased, and valleys receive their greatest load, with the result that their sides close inwards. To support the idea that water load plays an important part in the fluctuation of level we have the repeated observations that during wet weather, when we see water accumulating in the beds of valleys, the heeling over of the booms of horizontal pendulums is towards the loaded district.

The main point, however, to which I desire to draw attention is not so much the explanation of curious phenomena, but simply to the fact that Horizontal Pendulums may, under certain conditions, be influenced by hidden water loads. The investigations that this suggests should be of particular interest in certain parts of South Africa. For example, do the fluctuations of the subterranean water tapped in the Karoo affect the surface level? If they do, then the revelations of a pendulum may play an important part in the opening up and the settlement of a district.

Whether this type of seismograph will be used as an assistance in the prediction of weather is a matter worthy of some consideration. The Barometer gives the atmospheric pressure where it is installed. The Horizontal Pendulum, under certain conditions, swings to the

side, where pressure is at a maximum, or the side from which bad weather might be expected.

The most general and popular use of this instrument is that it yields records of all the great seismic disturbances in the world. From the character of a seismogram you can judge of the magnitude of the earthquake it represents. You can frequently say where it occurred, and when it occurred. This information is usually obtainable long before the arrival of cablegrams which, if they emanate from a devastated district, suffer not only delay, but may convey exaggerated and alarming impressions. Seismograms written by our earth have frequently extended, confirmed, or disproved telegrams written by man. To pressmen and the inquiring public seismograms have an increasing importance, and Africa, although it is the poorest earthquake-producing continent in the world, can with advantage to itself report upon disasters off and beyond its shores.

Large earthquakes are announcements of accelerations in hypogenic activity. When this ceases, and that which is epigenic becomes paramount, it would seem that the ultimate effects of surface denudation in general would be to reduce continents to sea level and to wipe out surfaces which are habitable. The panacea for such a fear rests in the idea that as mountains are washed down to load our sea boards, these may sink, whilst the high lands, which have been lightened, would be buoyed up. By such a process isostacy would save the features of our world.

11.—MEAN MONTHLY AND ANNUAL RELATIVE HUMIDITY CHARTS OF THE UNITED STATES.

By Kenneth S. Johnson, Harvard University.

(Received through Professor R. de C. Ward, Harvard University, and communicated by J. R. Sutton).

[Abstract.]

Loomis in 1880 * published a chart with relative humidity lines for a few stations east of the Rocky Mountains. There were but four such lines, and these were based on only one month's record—January, 1875—but the purpose which Loomis had in mind was accomplished, namely, to show that on the east side of the Rocky Mountains "there is a narrow belt of territory where the mean relative humidity is less than one-half."

In 1902 the U.S. Weather Bureau published † three charts of relative humidity, one for the year, one for January, and one for July. The charts are incomplete in that they do not cover all the months. Moreover, they are based on records of varying length, ranging from 4 to 14 years. The present charts for all the months and for the year are based on data for the uniform period of 14 years, from 1888-1901 ¶ In a few parts of the country, where the stations are scattered, records of slightly shorter periods have been used in determining the position of some of the lines, but in no case have the short period records been given equal weight with those of the 14-year period.

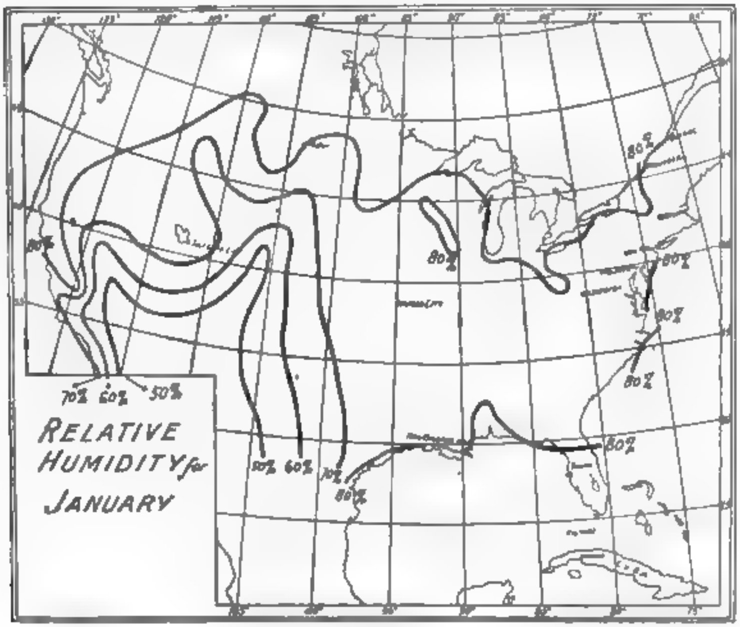
The curves are drawn for differences of 10 per cent. only; for the sake of clearness in presenting the main facts. Furthermore, the length of the records is not sufficient to warrant greater detail.

Among the most striking features shown on the charts is the uniform high relative humidity along the coasts, in contrast with which is the extremely low relative humidity in the S.W. interior, especially in Arizona, Nevada, S.E.California, and the adjacent districts. While the high relative humidity on the coast remains fairly constant throughout the year, the low in the interior basin (or, as it used to be called, the Great American Desert) becomes more marked as summer approaches, thereby increasing the already strong relative humidity-gradient between the Pacific coast and the interior.

Another interesting fact is the annual movement of the lines in the northern part of the interior basin. These travel north in summer, reaching the northern limit in June or July, returning south or perhaps entirely disappearing in winter.

Among other features worthy of note is the distorting effect of the Great Lakes, where the relative humidity tends to remain at or near 80%, an effect quite similar to that produced by the oceans. Also—a thing which rarely occurs—there is a prevailing north and south trend of the lines over the Great Plains in the vicinity of the 100th meridian, showing that the relative humidity there does not vary with the latitude.

* *American Journal of Science,* Third Series, Vol. XX., p. 22.
† Report of Chief of Weather Bureau, 1901-2, p. 320.
¶ Report of Chief of Weather Bureau, 1901-1902, p. 318.



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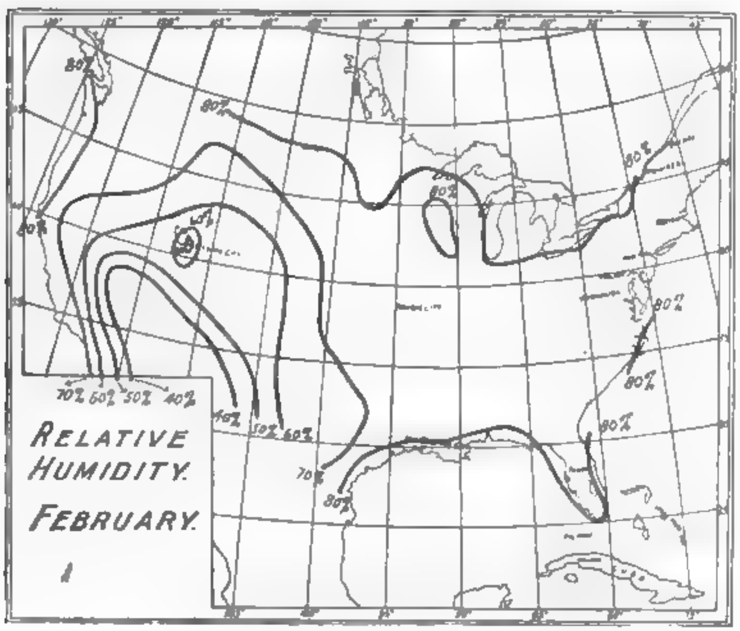

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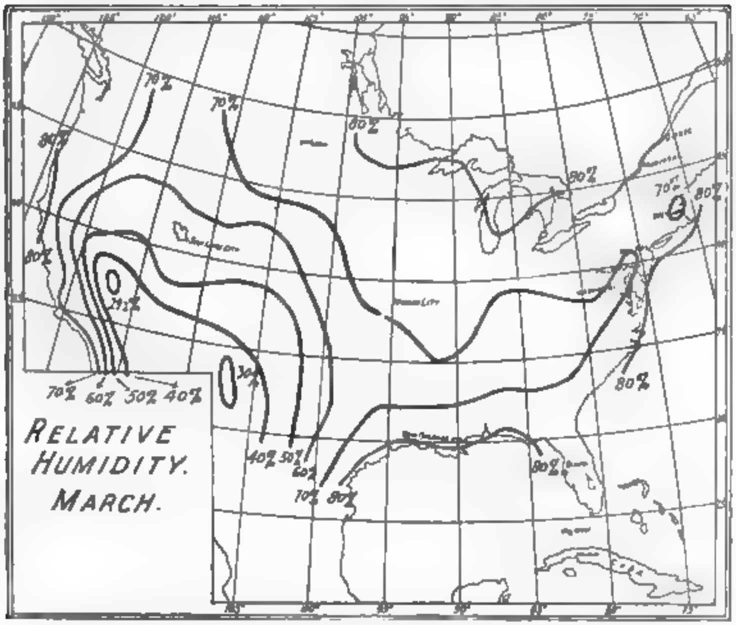

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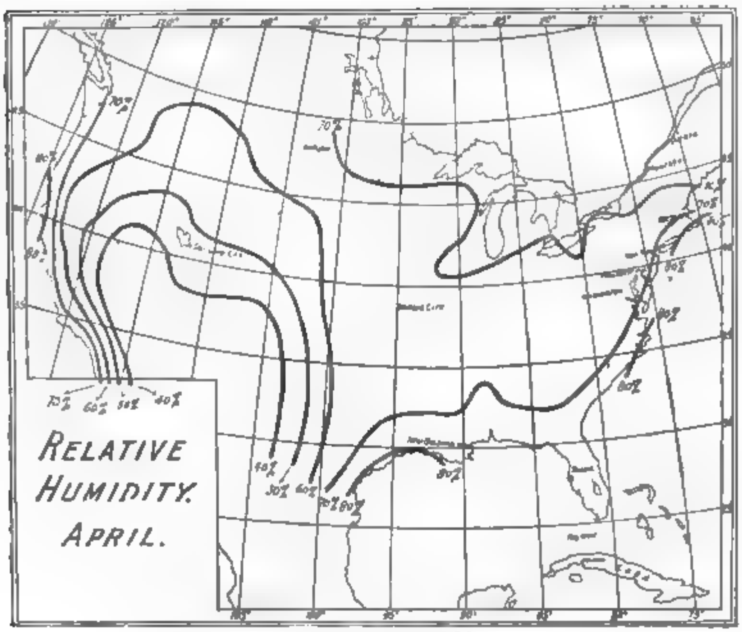

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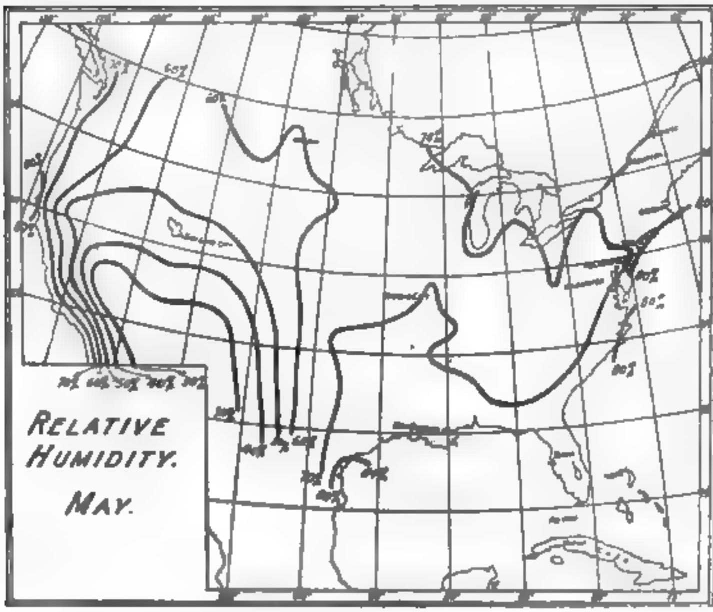

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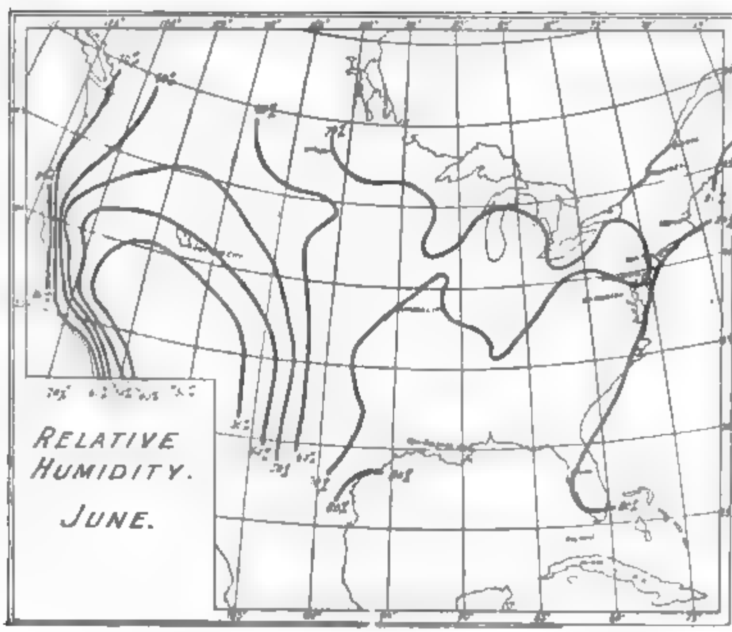

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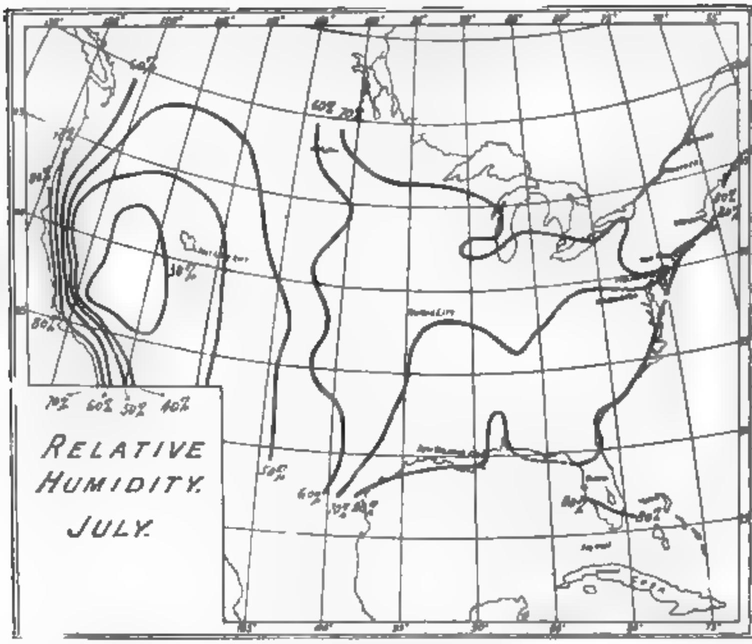

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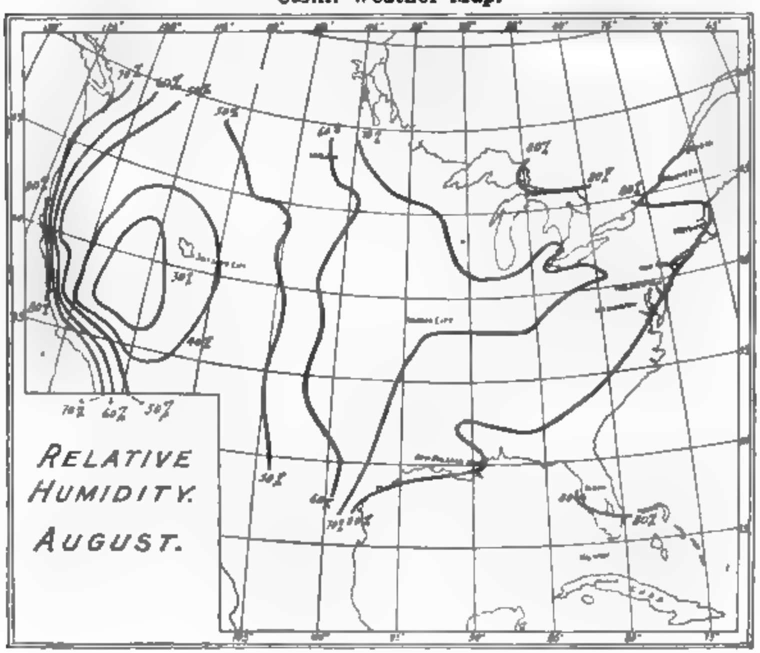

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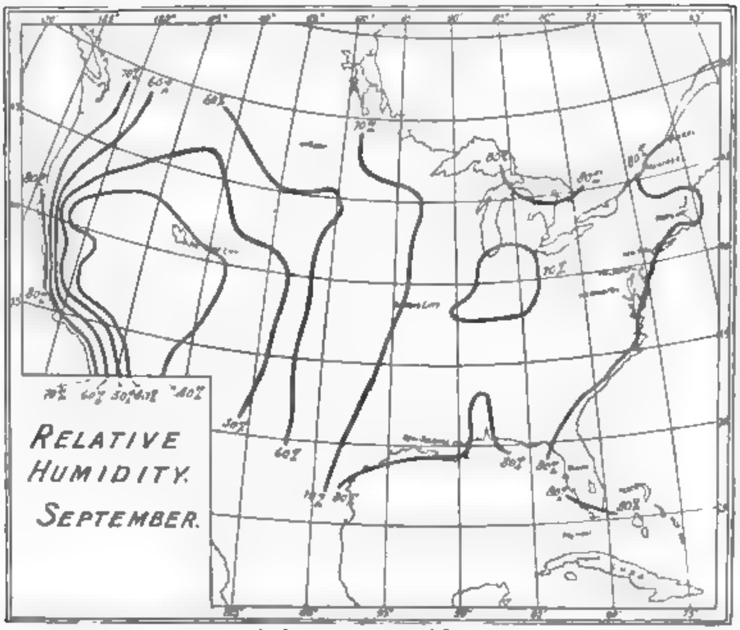

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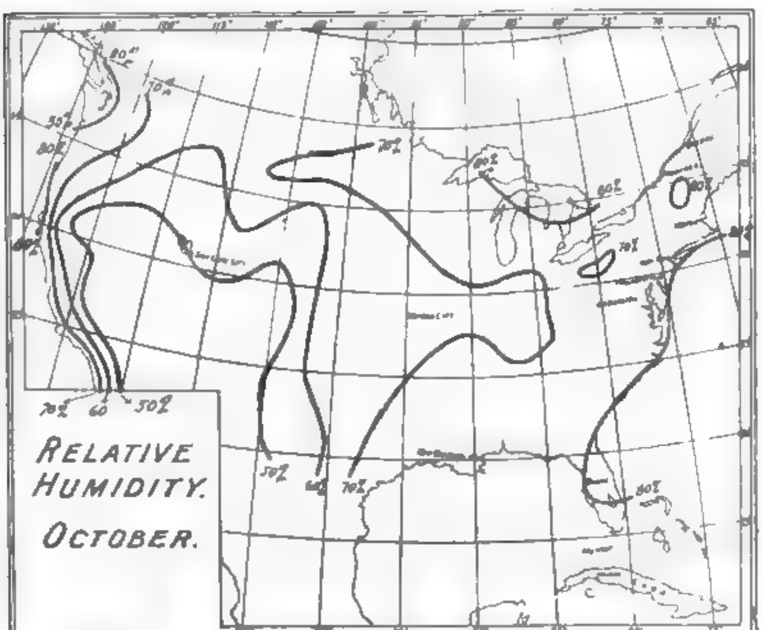

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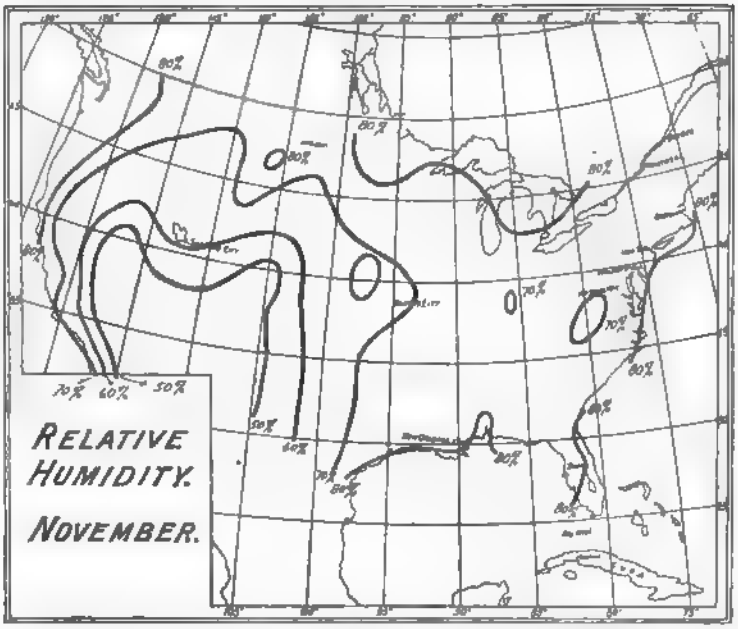

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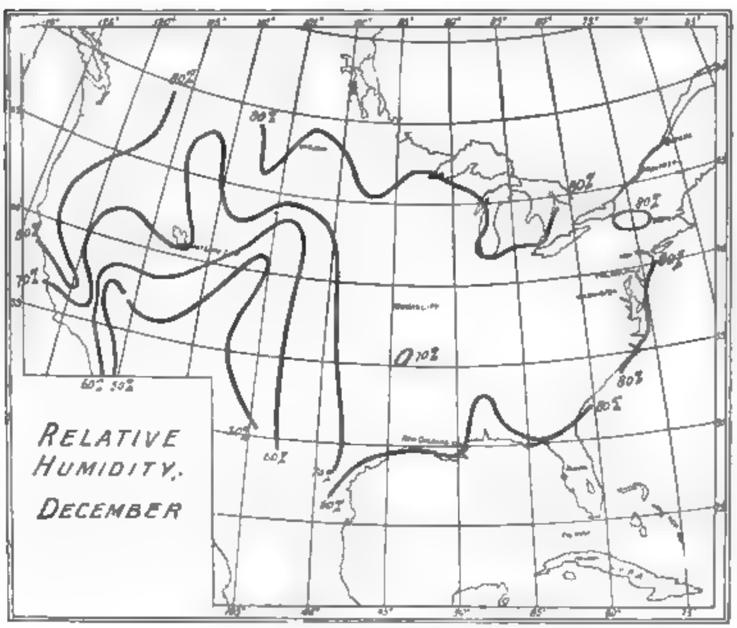

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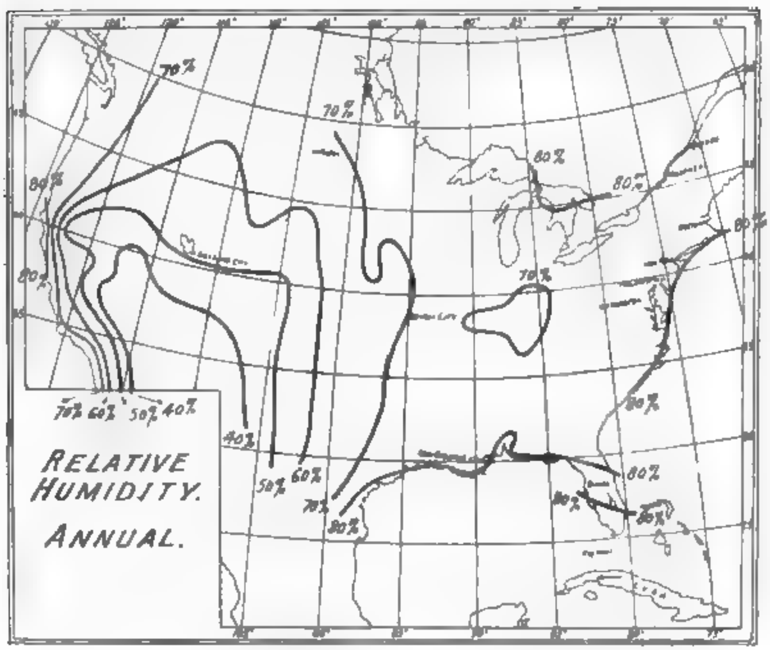

U.S.A. Weather Map.

12—A NEW SOLVENT FOR GOLD.

By James Moir, D.Sc

This Paper has been published in the Journal of the Chemical Metallurgical and Mining Society of South Africa.

13.—MAGNETIC OBSERVATORIES IN SOUTH AFRICA.

By Professor J. C. Beattie, D.Sc., F.R.S.E.

1. Distribution of Magnetic Observatories throughout the world.
2. History of Cape Magnetic Observatory and the attempts to revive it.
3. Purposes served by a Magnetic Observatory.
4. Suggested scheme for Permanent Magnetic Observatories in South Africa.

1.—Distribution of Magnetic Observatories Throughout the World.

There are at the present day between forty and fifty thoroughly equipped, permanent magnetic observatories in the world. Of these all but five are in the Northern Hemisphere. These five are Batavia in the Eastern Archipelago, Mauritius, Melbourne in Australia, Christchurch in New Zealand, and Córdova in South America. In Melbourne, Christchurch, and Mauritius the capital sum required for building and equipment and the current expenses, are provided by the respective local Governments. On the African Mainland itself the only observatory is Dar-es-Salaam in German East Africa, which is at present in course of erection. There are four in Great Britain, four in France, and four more under construction. Japan has six such observatories, and no European country except Turkey, Servia, Bulgaria, and Greece is without its magnetic observatory.

2.—History of Cape Magnetic Observatory and the Attempts to Revive It.

A permanent magnetic observatory was established at the Royal Observatory at the Cape in 1841. It continued in existence till 1853, when the building was burnt down, and many of the records lost. Since then, despite many attempts to resuscitate it, no fixed magnetic station has been in being. The British Association has several times moved in the matter. In its report of 1887 a committee appointed by the Association for the purpose of considering the best means of comparing and reducing magnetic observations reported "that the establishment of regular magnetic observatories at the Cape of Good Hope and in South America would materially contribute to our knowledge of earth magnetism." (British Association Report, 1887, p. 320). The same resolution was adopted in 1889 (B.A. Report, 1889, p. 50), and again in 1890 (B.A. Report, 1890, p. 173).

In 1891 the same committee reported that they had hopes that their recommendation of the establishment of a magnetic observatory was about to be carried out under the direction of Her Majesty's Astronomer at the Cape, and at the expense of the Admiralty (B.A. Report, 1891, p. 150). The negotiations fell through, however.

After this date the matter was allowed to rest for some time. It was again brought up in 1898 by the International Meteorological Conference (B.A. Report, 1898, p. 762). By this time electric

tramways had been laid down in Cape Town and its suburbs, and the Royal Observatory, which is within a mile of the rails was no longer a suitable place for a permanent magnetic observatory. The Council of the British Association had therefore to make their appeal to the Colonial Government. The Association transmitted the resolution of the International Conference—after having considered and approved of it—to the Cape Government through the then High Commissioner, Sir Alfred Milner. The Cape Premier replied that his Government did not regard as practicable the immediate provision of funds for the carrying out of the scheme (B.A. Report, 1899, p. lxxxv.).

3.—PURPOSES SERVED BY A MAGNETIC OBSERVATORY.

The proper carrying out of the magnetic survey of a country requires the presence of such an observatory. By means of the latter corrections can be made on field observations which have been taken at periods of magnetic disturbance.

Such an observatory is absolutely essential for the determination of the change in the value of the magnetic elements from year to year. The magnetic chart of the seas neighbouring a land can only be correctly made when this change is known.

Observation shows that the secular change of the magnetic elements is not a world-wide progress of the magnetic needle moving regularly in certain directions, but that in addition there are local causes at work in certain regions. In other words, a permanent magnetic station in England is of no help to magnetism in South Africa. In South Africa at present it is impossible to tell what the magnetic state of any part of it will be ten years hence. With the establishment of properly equipped and properly situated observatories in combination with a thorough magnetic survey it will, it is hoped, be possible in a few years' time to tell at least two or three years ahead what will be the value of magnetic elements in and about South Africa.

In this way the safe sailing of the shipping frequenting our shores will be greatly facilitated. Captain Creak says, in his address as President of the Geographical Section of the British Association in 1903, after expressing regret that there was still no permanent station at the Cape: "Of the value of magnetic charts for different epochs, I have much to say, as they are required for purely scientific enquiry as well as for practical uses. It is only by this means we can really compare the enormous changes which take place in the magnetism of the globe as a whole; they are useful to the miner, but considerably more so to the seaman. Had it not been for the charts compiled from the results of the untiring labours of travellers by land, and observers at sea, in the field of terrestrial magnetism during the last century, not only would Science have been miserably poorer, but it is not too much to say that the modern iron or steel steamship traversing the sea on the darkest night at great speed would have been almost an impossibility; whereas with their aid the modern

navigators can drive their ships at a speed of 26.5 statute miles an hour with comparative confidence, even when neither sun, moon, or stars are appearing."

4.—SUGGESTED SCHEME FOR PERMANENT MAGNETIC OBSERVATORIES IN SOUTH AFRICA.

In offering any suggestions for remedying the lack of permanent magnetic observatories in South Africa, several points have to be taken into consideration. In the first place, the size of the region demands that several observatories be founded. Secondly, the position of these must be chosen in such a way that their usefulness will not be destroyed at a later period by the magnetic fields due to the use of electricity for lighting or for locomotion. This latter consideration demands that no observatory be founded within a distance less than 10 miles of any town which may have electric trams within the next fifty years. Two such stations should be established in the Cape Colony, one at Matjesfontein, the other at Lovedale, one at Bloemfontein, one at Bulawayo, and one in Natal, somewhere on the coast. In addition to the magnetic instruments, instruments for the regular record of atmosphere electricity phenomena should be provided.

The cost per station would be about £3,000; and each station except Matjesfontein would require an observer capable of taking absolute measurement of the various magnetic elements.

The photographic records might be sent to a central office, just as meteorological records are at present; there the work of reduction could be carried out. The establishment of observatories is of no value if the observations are not reduced and published as quickly as possible. Such an arrangement as this would ensure that. An additional advantage of such a central office would be to carry out systematic comparisons with the different instruments of the various observatories, thus ensuring comparability. The advantage of having a number of such observatories spread at different heights over such a large surface would be incalculable; many of the outstanding problems in magnetism and atmospheric electricity could be attacked in a rational manner.

14.—ACCELERATION OF GRAVITY AT JOHANNESBURG.

By Prof. R. A. Lehfeldt, D.Sc.

[Abstract.]

The value of gravity has not, so far as I am aware, been measured anywhere on the South African table land. On taking charge of the physical laboratory at Johannesburg I thought it desirable to make a provisional determination with such means as were at hand. There was a pendulum, intended for the use of students, of the usual Borda's pattern, and a cathetometer by Pye of Cambridge, the scale being engraved on the steel upright of the instrument. For time measurements there was a chronometer, which, by the kindness of Mr. Innes, Director of the Government Meteorological Observatory, Johannesburg, could be rated telephonically by comparison with the Observatory standard clock. The dimensions of the pendulum were as follows :—

Ball diameter 7.783 cm. Mass 1730 gms.
Nut at top of Ball, thickness 0.238 cm.
Wire (Pianoforte steel), mass 0.011 gm. per cm.
Knife edge attachment, mass 53 gms. (radius of gyration about knife edge)^{2}13.
centre of inertia 2.1 cms. below knife edge.

The laboratory possessed a steel beam two metres long, forming part of an optical bench. In this a V groove was cut, and a set of eight steel bars, each 248 mm. long, with rounded ends, made to slide in the groove. The beam was mounted vertically alongside the pendulum, and a set square used to mark the position of (a) the top of the nut on the ball, (b) the plane (of glass) on which the knife-edge works. These levels were marked by scratches on paper pasted across the steel beam. The length of the suspending wire was so chosen that the distance between the scratches was a few millimetres longer than the length of a whole number of the steel bars. The beam was then laid horizontally, the bars placed in the groove, and the short lengths over at the ends measured by a travelling microscope. The lengths of the bars themselves were measured by the scale and vernier of the cathetometer, using the instruments as a pair of calipers. Since the chief error of Borda's pendulum is usually taken to be the uncertainty as to whether the centre of inertia of the ball coincides with its centre of figure, two lengths of wire were used, one about equal to seven rods, the other to four. The length from knife edge to centre of ball was obtained as described, and the length of the equivalent simple pendulum calculated by means of the centre of inertia and moment of inertia of the whole system. The results were :—

179.19 cm.	104.07 cm.

To observe the time of vibration the chronometer, illuminated by an incandescent lamp, was placed on a table in front of the pendulum,

a small mirror fixed to wall behind it, and a telescope arranged to observe the seconds hand of the chronometer reflected in the mirror. The pendulum wire (slightly out of focus, of course) swung in front of the mirror, and could therefore be seen along with the chronometer. A set of five thousand complete oscillations was observed, the time being noted for every hundredth up to 2000, and every five hundredth from there onwards. The period for the first two thousand and for the whole set was calculated in the usual manner (0 to 2500, 500 to 3000, etc) and corrected for amplitude.

Semiamplitude at start	8 cm.	$5\frac{1}{2}$ cm.
" finish	3 cm.	$2\frac{1}{2}$ cm.
Temperature	10° to 18°	7° to 13°.
Chronometer loses 1 in 18000.		
Corrected period	2.68845	2.0490.

$$g = 4\,\Pi^2 \frac{179.19}{2.68845^2} \;\Big|\; = 4\,\Pi^2 \frac{104.07}{2.0490^2}$$

$$= 978.71 \;\Big|\; = 978.59.$$

The difference between numbers may be accidental or may be due to an error in the position of the centre of inertia of the ball. I think it is due to the former cause chiefly, and as the measurements cannot claim an accuracy beyond the first place of decimals, I take the result to be :—

978.7.

The latitude of the physical laboratory is 26° 11′ south, and its altitude 1753 metres. Helmert's formula,

$$g = 980.62 - 2.6 \cos 2\phi - \frac{h}{3300} \text{ gives } 978.50.$$

for a table land theory would give a correction for altitude of only $\frac{5}{8}$ as great; it is usually stated that the table land formula is inapplicable owing to displacements in the density of the underlying strata, but this would seem not to be the case with the great South African table land, as the formula

$$g = 980.62 - 2.6 \cos 2\phi - \frac{5}{8} \cdot \frac{h}{3300} \text{ gives } g = 978.70$$

in agreement with the observations. Since there are only two really large table lands in the world—South Africa and Tibet—some geophysical interest attaches to the results, and it is hoped they may be repeated with better apparatus.

SECTION B.

Anthropology, Ethnology, Bacteriology, Botany, Geography, Geology, Mineralogy, and Zoology.

Section B.

Capt. Thos. Quentral, F.G.S., M.I.Mech.E., was President of this Section, but did not submit an Official Address for publication.

15—VARIATIONS IN THE GEOMETRICA-GROUP OF SOUTH AFRICAN TORTOISES.

By J. E. Duerden, Ph.D., A.R.C.S.
Professor of Zoology, Rhodes University College; Keeper of Zoological Department, Albany Museum.

CONTENTS.

INTRODUCTION.

In South Africa there occurs an extremely well-defined group of tortoises, all the species of which are referred to by Prof. G. A. Boulenger, in the British Museum Catalogue of Chelonians, as "allied to *Testudo geometrica*." They are readily distinguished from other tortoises by having a black or dark brown carapace, each shield of which is conical with bright yellow rays extending from

the central areola. The original type, *Testudo geometrica*, is a well-known Linnean species, found in the Cape District.

With the extended exploration of South Africa, more and more of the *geometrica*-like tortoises have been discovered, so that at the present time the group comprises ten described species:—1, *Testudo geometrica*, Linneus, 1766; 2, *T. oculifera*, Kuhl, 1820; 3, *T. tentoria*, Bell, 1828; 4, *T. verreauxii*, Smith, 1839; 5, *T. trimeni*, Boulenger, 1886; 6, *T. smithii*, Boulenger, 1886; 7, *T. fiskii*, Boulenger, 1886; 8, *T. strauchi*, Lidth de Jeude, 1893; 9, *T. seimundi*, Boulenger, 1903; 10, *T. boettgeri*, Siebenrock, 1904. It is a significant fact that five of the species have been founded on single specimens, and in not more than two or three instances has a large number of specimens been available for determining the limits of variation or the relationship of the species to others previously described.

The fact that so many species of a clearly defined group occur in one region, all acknowledged to be very closely allied, suggested that a thorough study of the *geometrica*-tortoises on the spot might yield results of importance as regards the origin of the variations, their degree of distinctness, and their relationships; in other words, might illustrate in some way the method of evolution of the different species. For the prosecution of such a study large numbers of specimens are required, obtained from as many different sources as possible. From efforts already made, about 300 examples have been procured from various localities in South Africa. The collection can probably be regarded as fairly representative of the different types of the *geometrica*-group, though a perfect study of this kind would require that every individual specimen, living and dead, should be compared, and, where possible, the results stated in statistical terms. For specimens received acknowledgments are due to the Director of the South African Museum, Cape Town, of the Natal Government Museum, and of the King William's Town Museum, as well as to numerous contributors throughout South Africa, among whom Mr. S. C. Cronwright Schreiner, M.L.A., deserves special mention.

During the progress of the work, as more and more specimens became available for study, the more difficult became the task of arranging them systematically among the recognized species, and the more evidence was accumulated as to the close relationship of the species so-called, thereby confirming the idea of their common genetic nature. Moreover, it soon became manifest that the different series include some remarkable transitional forms, and also that characters incipient or fluctuating in one group of specimens were well developed or fixed in other groups. In every direction evidence was afforded of determinate variation or variation along definite lines (orthogenesis) in contrast with indeterminate or discontinuous variation (mutation).

Though the occurrence of transitional series of organisms is by no means unfamiliar to the zoologist, yet it is very desirable that they should all be thoroughly worked out with the object of discovering what particular new light they may shed upon the all-important

which narrow black bands are displayed. The following tints are found to occur: Pale yellow or straw colour, lemon, light and dark orange, reddish yellow, yellowish brown, and liver red. Usually any one tint is characteristic of an individual, but occasionally the distal part of the ray is darker than the part near the areola. The colours are rarely very clear and bright on the natural shell, but when the latter is wetted or rubbed with oil they are displayed in a brilliant manner.

Though the yellow rays present very varied appearances in the different sub-groups, a general underlying plan can be traced throughout, and followed in its greater and greater elaboration through the series. The simplest condition is that found in *tentoria*, and the most complex in *oculifera*. In the former a number of simple yellow bands radiate from the areola, which is also yellow; some of the rays extend all the way from the areola to the margin, while others are shorter, due to incompletion either proximally or distally. The width of the ray also varies much, and may be the same throughout or increased distally; frequently a broad ray is bifid distally. In general, the rays of one shield show no correspondence in position with those of the adjacent shields, so that no complex geometrical pattern for the whole shell is possible.

The neural and costal shields of *tentoria* are roughly quadrangular in their basal outline, and in some individuals there is a tendency for the rays passing to the four angles of the shields to be more conspicuous than those intermediate, and also for those of adjacent shields to correspond, thereby giving a more definite geometrical plan. All the types of the *geometrica*-group show this to be the fundamental disposition of the rays on both the neural and costal plates. The principal rays extend from the areola to the angles of the shields, and these four are the most conspicuous rays; midway between two adjacent principal rays may be another ray, and alternating with these two series may be others of lesser rank. The four principal rays will be spoken of as *primary;* the four intermediate, one or more of which may be wanting, will be *secondary* rays; and the third series, not always present, will be *tertiary* rays. On all the shields the four primary rays are always conspicuous, and, in the more complex patterns, such as those of *oculifera*, they are bifurcated distally. The secondary rays alternate with the primary, and vary much in the extent of their development; rarely they are all wanting on individual shields. Frequently the two longitudinal secondary rays of one shield correspond with those of the two adjacent shields, one in front and one behind, and thus give rise to a continuous yellow band, which is median along the neural shields and lateral along the costals on each side. The tertiary rays are generally imperfectly developed, and are rarely numerous except in certain *tentoria*. By the continuity of the two primary rays of one shield with the two primary rays of an adjacent shield there is produced a "diamond pattern" which, combined with a median band, gives an ocellated character to the carapace. This is very well shown in some specimens of the *verreauxii* sub-group (see Boulenger's

figure of *T. fiskii*, P.Z.S., 1886, pl. LVIII.), and more especially in *oculifera*. The middle of the ocellus is constituted by the lateral secondaries, and, if these are bifurcated, still more distinctive "ocelli" are produced.

When the simple ray type of coloration found in the *tentoria* sub-group is compared with the complex ocellated pattern of some of the *oculifera* sub-group, the two would seem to be very divergent and unrelated, and it is only by studying intermediate stages that the pattern of *oculifera* admits of comparison with that of *tentoria*. The members of the *verreauxii* sub-group are particularly instructive for this purpose. They include all stages in the prominence of the primary rays and their correspondence with those of adjacent shields so as to strengthen the geometrical plan. Ocelli are also very clearly indicated in some of the extreme members. The *geometrica* sub-group also shows the same tendency towards the regularity and correspondence of the rays, but to a much less degree than most *verreauxii*; indeed the colour pattern of some of its members cannot be distinguished from that of *tentoria*. In *trimeni* the pattern seems to have become more fixed and regular, and is transitional in character; rarely any of the tertiary rays are present, and usually not all the four secondaries.

Taking all the representatives of the *geometrica*-group into account, it becomes an easy matter to arrange a continuous series showing all the transitional stages from the simple ray pattern of *tentoria* to the very complex, ocellated display of *oculifera*. No one can question that all the colour variations are genetically related in a direct line from such a form as *tentoria* to that of *oculifera*, and that they represent a strictly continuous type of transformation. Corresponding rays can be traced all through the series, the modifications consisting in the closer relationship of those of one shield with those of adjacent shields, and in minor changes such as bifurcations. In certain of the sub-groups one transitional stage appears as if becoming fixed, while in other sub-groups another stage predominates, but probably nowhere do we get two individuals exactly alike. Even in specimens of any sub-group from the same locality there are great differences in the number of complete and incomplete rays present, and in the regularity of the pattern. While conforming closely to the general plan of the sub-group, the minor variations are innumerable.

b. COLORATION OF PLASTRON.

The plastron also affords a very complete gradational series in the production of an elaborate colour pattern. The coloration of certain members of the *tentoria* sub-group may be regarded as the extreme type of simplicity, while that of *oculifera* represents the extreme of complexity. Between these two there is a complete varietal series, showing that all are genetically related.

In what may be considered as a typical *tentoria*, the whole of the central part of the plastron is uniformly dark brown or nearly

black, while the sides are a light yellow, the boundary between the two being sharply defined. In some specimens from the same sub-group the beginnings of a breaking up of the central patch into separate radii are represented, and triangular rays also begin to appear on the yellow sides. The latter variation is well marked in specimens of *tentoria* from the Hex River Valley. The same stage is also characteristic of *trimeni*, an excellent representation of which is given by Boulenger, 1886, pl. LVII. In *geometrica* the middle patch is likewise partly broken up into definite rays, and rays are also developed along the sides. Most of the rays in these instances are densest at the margin of the plastral shields, and start from the anterior suture, though some originate from the middle suture. A close comparison shows that the rays in the different types correspond with one another, ray for ray.

In the *verreauxii* sub-group the plastron is at times only a faint, dirty brown, perhaps a little darker in the middle. This variation is represented by Boulenger in his figure of *T. fiskii*, 1886, pl. LVIII. Frequently, however, in *verreauxii* the plastron is strongly rayed with black or dark brown in a regular fashion, the individual rays corresponding with those of the forms just mentioned. Boulenger's figure of *T. smithii* shows this stage (B.M.C., pl. IV.), while that of *T. seimundi* (1903, pl. XVII.) displays it in an incipient condition. So far, then, as the plastron in *verreauxii* is rayed, the arrangement of the rays is exactly like that in other sub-groups.

The number of the dark brown rays on the plastral shields, and the complexity of the pattern produced thereby, reach their climax in the *oculifera* sub-group. Here the whole plastron has a yellow background on which are dark brown or black rays, arranged in a more or less regular manner, so as to produce a geometrical pattern. Each specimen presents a similar plan, with many variations in such details as the width of the rays, their number, and curvature. But each of the principal rays has its exact counterpart in *verreauxii* and the others; the number of rays may be increased by the partial or complete splitting of individual rays, but not by the intercalation of any new rays. The extreme rayed condition displayed in *oculifera* is foreshadowed in a complete gradational series, beginning with the uniform black and yellow of certain *tentoria*.

Thus, as regards the coloration of the plastron, we reach the same results as from a study of the coloration of the carapace. Starting with the simple condition found in certain members of the *tentoria* sub-group, we obtain a transitional series of variations leading to the very complex condition characteristic of the *oculifera* sub-group. Exactly corresponding rays can be traced in both carapace and plastron from an incipient stage to a very complex pattern of the same elements. In the plastron, however, we commence with a single uniformly black patch, and then trace its differentiation into separate rays, accompanied by the appearance of new rays on the sides, while in the carapace no new elements are introduced at any stage.

As regards the coloration of both the carapace and plastron, no additional type of variation is anywhere introduced. We have corresponding series of rays in each, and evolution consists in the elaboration of features common to all at one stage or another. The passage from one extreme to the other is by direct and gradual variation. The great variation in details shown in different individuals from the same locality indicates that the plan of coloration is not yet wholly fixed and permanent in any sub-group, though within varietal limitations it can be considered as characteristic.

c. AXILLARY AND INGUINAL SHIELDS.

Siebenrock, in his paper, "Die südafrikanischen Testudo-Arten der Geometrica-Gruppe s.l.," has established as a character of some diagnostic value within the *geometrica*-group the occurrence of either one or two axillary shields; in fact, in his Synopsis of the species, he employs it as a means for separating the members of the group into two series. The first series includes *geometrica* and *oculifera*, both of which have only one axillary shield on each side, and the second all the remaining species, in which the axillary shield is divided into two small shields. The distinction holds as a general rule for all the specimens I have examined, but the acceptance of the character must not be taken as necessarily implying the direct relationship of the forms presenting the one or the other condition, for in nearly all other respects *geometrica* and *oculifera* are far apart.

The actual condition of the axillary shield within the *geometrica*-group is not so sharply defined as Siebenrock's use of it would imply. Both the axilliary and the inguinal shields represent the last remains of a series of numerous plates which in some Chelonia are intercalated on the bridge between the marginals and plastrals, and are known as *inframarginals*. Different members of the *geometrica*-group are found to vary as to the degree to which the reduction in number of these inframarginals has taken place. Both *geometrica* and *oculifera*, which in some other respects represent extreme types of variation, have the axillary shields reduced to one, and in nearly all the specimens of *oculifera* examined by me the shield is united with the femoral without any hint of a suture. In the other members of the group the reduction has not been carried so far, and a longitudinal series of two, three, or even four or five inframarginal shields may occur, which diminish in size in passing forwards. Individuals of *tentoria* generally show more than two shields; three or four are usually present, and occasionally one or two more, though not always in the same straight series. In *verreauxii* there are rarely three, usually there are two, the posterior somewhat larger than the anterior, and occasionally there is only one, while, as we have already seen, the latter condition is characteristic of *geometrica* and *oculifera*. Occasionally in *verreauxii* the number on one side is different from the number on the other.

Thus within the *geometrica*-group we have all variations represented in the reduction of the number of anterior inframarginals

from four or five to only one, and in an extreme case, where only one is present, it seems to have lost its individuality and become a part of the adjacent humeral shield. The fluctuating character at the intermediate stage is well shown in individuals of *verreauxii*, where the number may vary from one to three, and even differ on the two sides of the same individual; the number is a very fixed character in *oculifera* and *geometrica*, where in numerous specimens there is no hint of more than one.

The inguinal shield represents all that remains of the posterior inframarginals and is nearly always single, but in some individuals of *tentoria*, *verreauxii*, and *trimeni* one or two small additional shields are present. The additional shields vary in their degree of development in individuals of the same sub-group, and often on one side of a specimen as compared with the other, proving the character to be very fluctuating.

d. MARGIN OF CARAPACE.

The free edge of the carapace differs much in appearance in the various members of the *geometrica*-group. In some it is quite smooth and rounded, while in others the individual marginal scales are sharply angulated, when the margin is described as serrated. *Tentoria* may be taken as the extreme representative of the first type and *oculifera* of the second. As in other characters, all intermediate stages occur between these extremes. Not only *tentoria*, but also *trimeni* and *geometrica* present an almost unbroken margin, both anteriorly and posteriorly; occasionally, however, there is a feeble serration, more marked along the hinder border. The carapace of the *verreauxii* sub-group is found to be very variable; both the anterior and posterior borders are nearly always serrated and upturned, but the degree to which the modifications are carried differs greatly. In *oculifera* the serrated upturned condition is always strongly pronounced, both in front and behind, and imparts a decided spinous character to the shell.

To summarise: the upturned serration is to be regarded as a fixed permanent character in *oculifera;* the almost smooth, rounded margin occurs in *tentoria*, *trimeni*, and *geometrica; verreauxii* is undoubtedly transitional between the two, some individuals approach *tentoria* and others *oculifera.*

Frequently there occurs an irregular longitudinal shallow grooving towards the lower edge of the marginal plates, most conspicuous in the median shields united with the bridge. It is pronounced in some members of the *tentoria*, *trimeni*, and *verreauxii* groups, but has little diagnostic value.

e. MARGINO-COSTAL ANGLE.

In several of the *geometrica* sub-groups there is a strongly marked longitudinal depression or groove which separates the marginal series of shields from the adjacent costals. The groove extends

all the way round, and is formed by the marginals being inclined at an angle with the costals, emphasized by a certain nodulation of the upper part of the marginals. In other sub-groups the angulation is altogether wanting, the surface of the carapace being uninterruptedly smooth along the junction of the two longitudinal series of plates. Between these two extremes all transitional variations are to be found.

The angulation seems to be most prominently and consistently developed in *trimeni*, and the marginals here constitute a conspicuous swollen border to the carapace. In *tentoria* the character is often as well marked as in *trimeni*, but in some individuals it has nearly disappeared. The *verreauxii*-group, as in so many other features, is decidedly intermediate; the angulation is rarely so marked as in *trimeni* and *tentoria*, and is sometimes wholly wanting; even one side may differ considerably from the other.

Geometrica and *oculifera* are very pronounced types of the smooth condition, the costal shields passing almost insensibly into the marginals and continuing at the same inclination. Old and young specimens, however, differ a little; in the latter there is usually some suggestion of angularity, which disappears with age.

From the above brief mention of the condition of the margino-costal angle in the various sub-groups, it is manifest that a complete gradational series of variations exists between the two extreme types. A certain degree of fixity in extreme angulation is presented by *trimeni* and *tentoria*, *verreauxii* is remarkably fluctuating, and *oculifera* and *geometrica* are practically constant as regards their smoothness.

f. NUCHAL SHIELD.

The size and shape of the nuchal shield are characters which have been found to be of diagnostic importance within the *geometrica*-group, and justly so were the extreme variations alone to be taken into consideration; but transitional series are forthcoming here as in the other characteristics, and indicate that though the structure may be permanently fixed in certain types yet in no one sub-group has it become sharply separated from others.

The shield is least developed in *tentoria* and largest in *oculifera*. In the former species it may be so insignificant as to be invisible from above, but a rudiment may be seen on the under surface; in others of the same species it is seen from above as a narrow border to the first neural shield, and in a few it is longer than broad. In the forms embraced under *trimeni* the nuchal shield is at about the same stage of development as in *tentoria*.

In all the members of the *verreauxii* sub-group the nuchal shield is better developed than in most *tentoria*, though of similar form; as seen from above it appears as a nearly rectangular projection from the front of the first neural, somewhat longer than broad, and usually a little broader behind than in front.

An extreme variation is reached in some representatives of the *geometrica* sub-group; the shield has become very narrow, two or three times longer than broad, and pointed at its free end. In others of the same sub-group it differs but little from that met with in certain of the *tentoria* sub-group. The shield is altogether absent in the single specimen to which van Lidth de Jeude has given the name of *T. strauchi*. It is possible that this may be an exceptional specimen of *T. geometrica*.

Another extreme is presented by *oculifera*. Here the shield is comparatively large and triangular, the base of the isosceles triangle being a little shorter than the sides. The free end, constituted by the areola, is pointed.

Thus, as regards the nuchal shield in the *geometrica*-group, there is a very decided gradational series; it is almost absent in *tentoria*, variable in *verreauxii*, and is conspicuously developed in *oculifera; geometrica* represents a somewhat specialized, long, narrow variation, which may, perhaps, be eliminated altogether.

g. ANTEBRACHIAL SHIELDS.

Along the front or anterior border of the fore-arm of all the members of the *geometrica*-group a series of specially enlarged imbricating scales occur which effectually cover the front opening of the shell when the animal is retracted, and thereby protect the head and other vulnerable parts of the anterior region. The scales vary greatly in number and character in the different types, and, for the most part, grade insensibly into the smaller and more uniform scales at the back of the fore-arm. Certain specimens of *tentoria* present what may be considered as the simplest condition. Three or four well-defined, longitudinal rows of scales of nearly equal size are present, making four or five oblique transverse rows. The scales along the two middle rows are larger and more regular in size than those of the marginal rows, and all are elongated and narrow.

The variations from the *tentoria* type are in the direction of reduction in the number of prominent scales, and the increase in size of the few remaining, culminating in a single nodular shield, which is much larger and stronger than the rest. At one extreme may be placed *geometrica*, bearing only five or six moderately enlarged scales, so far apart as not to be overlapping, and at the other extreme is *oculifera*, with one specially enlarged and thickened scale along with a few moderately large ones on the upper and outer borders.

All transition variations are to be found between the condition characteristic of *tentoria* and that met with in *oculifera*, clearly indicating that the one type has been derived from the other. Even in *tentoria* specimens are sometimes found in which the scales have lost somewhat of their elongated character, and one or two of the middle scales have become larger than the rest; but in *verreauxii* it is usual to find the number of enlarged scales already reduced, and a middle one much increased in size, even becoming sub-conical. This condition passes insensibly into that of *oculifera*

where the central shields have disappeared, with the exception of one which is much enlarged, thickened, and excentrically conical.

Transitional stages towards the variation in *geometrica* are not represented in the collections, but no doubt such would be found in a larger series of specimens from the Western Province of Cape Colony. As compared with *tentoria,* there has been a reduction in the number of prominent scales without any tendency for one to become larger than the others. Five or six enlarged shields occur, but are so far apart as not to be imbricating. It clearly represents a different type of modification from that culminating in *oculifera.*

Testudo trimeni represents another slightly different type in the arrangement and character of the arm shields, but one towards which there are numerous intermediate stages. In the most characteristic specimens are four specially enlarged, flattened shields, arranged in a continuous median row from the elbow to the fingers, and along the two sides of this row are a series of scales moderately enlarged. It is found, however, on comparing the shields of a number of specimens of *trimeni* with those of *tentoria* and *verreauxii,* that all intermediate varieties from one extreme to the other can be traced.

Therefore as regards the enlarged antebrachial shields at least four more or less well-defined types of variation are represented in the *geometrica*-group: 1, the numerous, elongated, imbricating shields of most *tentoria;* 2, the few scattered, non-imbricating shields of *geometrica;* 3, the single row of four flattened shields in *trimeni;* 4, the single, greatly enlarged, thickened, sub-conical shield of *oculifera.* Between these extreme types, with perhaps the exception of *geometrica,* all intermediate or transitional stages are still to be obtained. With all these facts before one, there can be no question that the extremes represent so many lines of variations or departures from a common source.

h. FEMORAL TUBERCLE.

The femoral tubercle is a greatly enlarged, conical shield, situated upon the back region of the thigh, which, when the animal is retracted, assists in the protection of the vulnerable parts at the hinder opening of the shell. The tubercle may be single on each side, but is frequently surrounded by others of much smaller size, inclined against it after the manner of buttresses; occasionally on each side are two tubercles of equal size, or one may be larger than the other. In addition to the strictly femoral tubercle a number of enlarged shields sometimes occur, arranged in longitudinal rows along the sides and over the upper surface of the short tail, and without doubt also serve to protect this region.

The femoral tubercle is developed to very different degrees in the various assemblages of the *geometrica*-group. Boulenger, in his British Museum Catalogue, employs the character as a means of separating *geometrica, verreauxii,* and *trimeni* from the rest; the three mentioned are stated to have no enlarged femoral tubercle, while such is present in the others. As regards *geometrica,* the

distinction holds for the few specimens I have examined, but there is little doubt that if more were available some would be found with the tubercle developed to a greater or less degree. *Verreauxii* was first described by Smith without mentioning the femoral tubercle, and this was taken by Boulenger (1886, p. 541) to imply the absence of such a structure. However, among the many individuals of the *verreauxii* type, obtained from the same locality as Smith's (sources of the Orange River), I find practically every specimen is provided with an enlarged tubercle, so there can be little doubt that Smith's *verreauxii* had enlarged femoral tubercles. Siebenrock (1904, p. 313) also states that a form he identifies as *verreauxii* has very large femoral shields.

In *trimeni* the femoral tubercle is altogether absent in some specimens, as stated by Boulenger, yet it is present in others, though never enlarged as much as in *tentoria* and *oculifera*. The conditions in *tentoria* are significant as regards the fluctuating nature of the shield. In some individuals it is wholly absent, in others it is moderately developed, while in others again it is strongly developed, and may even be buttressed by smaller ones. The tubercle reaches its maximum in *verreauxii*, where it is always a very prominent, conical shield, often with a number of much enlarged shields around it, or sometimes with only another of equal or nearly equal size. Also in *oculifera* the femoral tubercle is always a strong conical projection, but is rarely buttressed by smaller shields.

We may summarize by saying that the femoral tubercle is either absent or only feebly developed in *geometrica* and *trimeni;* that all stages from its absence to full development occur in *tentoria;* that it reaches its extreme development in *verreauxii*, where it is often supported by other smaller shields; and that it exists as a single, much enlarged shield in *oculifera*. It is a fluctuating character in the first three groups, but constant in the two latter groups, and there is a direct line of variations from one extreme of its development to the other.

i. FORM OF SHIELDS OF CARAPACE AND PLASTRON.

Much diversity in shape is presented by the individual shields of the carapace, that is, whether flat or elevated in a conical manner; and by this character the general appearance of the shell is largely determined. The extreme conical condition is afforded by many specimens of *tentoria*, where each shield is conspicuously elevated, the neural members somewhat more than the costal; the extreme of flatness is to be found in the *oculifera* sub-group; and between these two every intermediate stage can be obtained. The knobbed character can scarcely be regarded as constant for any of the species; even some specimens of *tentoria* have almost perfectly flat shields, though coming from the same locality as others with strongly conical shields, and, on the other hand, some individuals of *oculifera* have the conical form rather well shown.

The same can be said of the *verreauxii* sub-group. Individuals can be selected in which the conical character is almost as marked

a feature as in the extremes of *tentoria*, and others in which the flatness is as complete as in extremes of *oculifera*. The condition seems more constant in *trimeni*, a moderately conical shape being the rule.

The form of the shields can probably be considered as one of the most variable of the taxonomic characters. All we are justified in saying is that the conical condition is usually emphasised in the *tentoria* sub-group, the flattened condition is more general in the *oculifera* sub-group, while between these extremes are all transitional stages, often in the same sub-group. As in so many other instances, the *tentoria*, *verreauxii*, and *oculifera* sub-groups include both the extremes and the intermediate stages of the character.

To a limited extent, Siebenrock has employed the relative sizes of the carapace shields for diagnostic purposes. Where only a few specimens are available, the character might be of some value, but among a large number it is found that little constancy is exhibited. The smaller variations in the relative sizes of the shields are largely determined by the general shape of the shield, whether conical or flat, and by the general shape of the shell, and, to a limited degree, these are dependent upon the adjacent shields. It is manifest that where so many variables are concerned the proportional size of any shield can scarcely be expected to be a fixed constant.

Both Boulenger and Siebenrock have utilized the relative sizes of the plastral shields, especially as represented by their median suture lines, as taxonomic characters, but in going over a large assemblage of individuals, even from one locality, the feature is found to be so variable as to be practically valueless for indicating relationships. In addition, the gulars and anals usually show sexual differences.

j. BEAK.

The variation of the beak,whether feebly or strongly hooked, has also served for diagnostic purposes. It is practically always strongly hooked in *oculifera*, but less consistently so in *verreauxii*; in *tentoria* it is rarely as strongly developed as in those mentioned, but is always feebly produced in *trimeni*. On the whole, the beak may be considered to have attained fixity of character in some groups, but to be very fluctuating in others, exhibiting all transitions from the feebly to the strongly hooked condition.

k. FRONTAL AND PREFRONTAL SHIELDS.

An examination has been made of the upper head shields in numerous examples of the different sub-groups of *geometrica* to determine if any constant character in their relative sizes or number could be established. Frequently there are two somewhat enlarged shields, evidently the prefrontal of other groups, distinguished from the rest, but they are by no means constant in any sub-group, nor is the arrangement of the others adjacent to them. Hence it is manifest that the head shields have not yet attained such constancy as can be utilized for systematic purposes.

2. DISCUSSION.

a. TYPE OF VARIATION.

In the foregoing sections we have examined the varying conditions presented by certain well-defined external characteristics within the many species of the *geometrica*-group, embracing practically all those relied upon for diagnostic purposes. We find a series of characters, each of which, when traced through different members of the group, can be seen to pass by almost insensible gradations from one extreme condition to another. The group as a whole presents us with innumerable stages in the phyletic process of transformation of individual characters; everywhere we have chains of forms from one extreme of the structure to the other. The extreme variations are so marked that were almost any one of them to become isolated by the elimination of its transitional stages there could be scarcely any hesitation in according specific rank to the individuals possessing it.

Taking any one of the characters, we find that all its variations form a continuous series from one extreme to the other; in every case it has been possible to show that the extreme elaboration of a character is reached by slow transitions from some simpler stage. There is no suggestion that characters have changed suddenly from one phase to another, but the variations have always taken place by intermediate stages along one or more direct trends. Even such complex geometrical colour patterns as those exhibited by the carapace and plastron of *oculifera* can be explained in terms of others less complex.

The type of variation which the *geometrica*-group illustrates is that known as the *direct, continuous,* or *determinate* method, in contrast with the *indirect, indeterminate,* or *haphazard* method. In every instance the evolution of a character consists of a gradual but direct change from one stage to another, without any suggestiveness of the sudden introduction of new characters, or of variation along uncertain lines. The studies therefore lend no support whatever to De Vries' Theory of Mutation, which "assumes that new species are produced from existing forms by sudden leaps," but serve to confirm the more generally accepted view that transformations are mostly brought about by slow, gradual changes. The changes of any one character may be in a single definite direction (orthogenesis), *e.g.*, coloration, axillary and inguinal shields, or in different directions (amphigenesis), *e.g.*, nuchal shield, antebrachial shields.

b. FIXITY AND PLASTICITY OF CHARACTERS.

On tracing any one character throughout the various sub-groups, it becomes abundantly manifest that the character in question has attained a certain permanence or fixity in some sub-groups while it is yet plastic or variable in others. To take the nuchal shield as an illustration. Within the *tentoria* sub-group we find all stages from its practical absence to a length of nearly a centimetre, even among

individuals from the same locality; in the *verreauxii* sub-group its size is fairly constant, and an enlargement of that found within the *tentoria* sub-group; in *oculifera* and *geometrica* it has very fixed and definite characters, being strongly triangular in one, and long and narrow in the other.

The femoral tubercle illustrates the same conditions. In the *tentoria*, *geometrica*, and *trimeni* sub-groups it may be wholly wanting or feebly developed, but in some *tentoria* it is represented by a large, conical upgrowth, around which the minute body shields begin to enlarge and project in a buttress-like manner. The last-mentioned condition is further exaggerated in the *verreauxii* sub-group, where the tubercle itself shows but little plasticity, while the accessory shields are very variable in number and size. In many individuals they altogether encircle the principal spine, while in others they are less in number, and may ultimately be represented by only one much enlarged shield adjacent to the original. In *oculifera* the principal tubercle is very constant in size, while the surrounding shields are never more than feebly developed.

The condition of the antebrachial shields throughout the group affords another similar illustration. Within a limited range they are very plastic in all the sub-groups, but in *oculifera* they exhibit fairly fixed characters.

Thus, taking almost any character in detail, we find that in some sub-groups it is in a strongly fluctuating condition, in different individuals it is in different stages of development, while in other sub-groups it everywhere presents approximately the same stage or condition. Taken as a whole, the individual characters in the *tentoria* sub-group are very unstable, and to a less degree this is the case with the *verreauxii* sub-group, while in *oculifera*, *trimeni*, and *geometrica* the variations are much more fixed. As will be shown more fully later, the *tentoria* and *verreauxii* sub-groups are to be regarded as transitional in very many ways, while *oculifera* is an extreme, more permanent sub-group, and, as would be expected, the individual characters are more fluctuating in transitional types than in extreme types.

The fluctuating condition may be taken as indicative of the activity of the processes of germinal selection, perhaps accompanied by environmental changes, and under isolation would be conducive to the establishment of new types, while the fixed condition is indicative of a cessation of germinal selection, perhaps due to constancy of environment, and is not conducive to the production of new forms.

c. INTRODUCTION OF NEW CHARACTERS.

The discussion of the individual characters has been limited to those which are of diagnostic importance, and which seemed of especial value for the present study. It is manifest that the work might have been extended by treating in the same manner all the internal structures, though probably with results only of the same kind. With one or two exceptions, all the characters noticed

are present at one stage or another of their elaboration throughout the whole of the *geometrica*-group. However pronounced a character may be, it is shown to be but a modification of one occurring in a simpler form elsewhere. Transformation has consisted in the elaboration of characters traceable throughout. With the exceptions to be mentioned below, there are no new features anywhere introduced; the differences are simply so many variations of characters common to all, they are quantitative rather than qualitative. Such a homogeneity serves to strengthen the idea of the close relationship of all the members, and of their common genetic source.

The femoral tubercle and its surrounding supplemental shields may in some ways be regarded as a new character introduced within the limits of the group, though found in some other species of *Testudo* and other genera of the family *Testudineæ*. The bony process is altogether wanting in some members of the *tentoria*, *geometrica*, and *trimeni* sub-groups, is but feebly developed in other examples of the same sub-groups, and in certain *tentoria* becomes very large and surrounded by additional shields. In the *verreauxii* sub-group it is always strongly developed, and usually accompanied by enlarged accessory shields, either all the way round or at only one or a few places. In the *oculifera* sub-group the bony tubercle remains, but the supplementary shields are usually wanting.

It would seem therefore that the tubercle on the back of the thigh is a character in process of either introduction or elimination within the *geometrica*-group. On the assumption that *tentoria* is nearest the original type, the character represents a new introduction, for it may be absent, incipient, or fully developed within the limits of the sub-group. When we reach the *verreauxii* sub-group it is a permanently fixed structure, appearing in every member, and developed to about the same degree, but the directive process has extended further and brought about a change in the minute skin shields around the tubercle; these have been enlarged, and evidently serve the same purpose as the principal spine. We may consider that the femoral tubercle has reached its maximum of possible development consonant with its usefulness, and any further modification along the same lines is possible only by the bringing in of more shields. But the method of carrying out this last transformation is not constant, for the shields in some form a complete circle around the primary, in others there are two or three, and in others only one.

In *oculifera* the tendency towards the elaboration of the femoral shields is not so strong as in *tentoria*. The principal tubercle is as large as in *tentoria*, but the accessory shields are either absent or developed to a much less degree. In many ways it has been shown that the *tentoria*, *verreauxii*, and *oculifera* sub-groups represent a gradational series, and the conception is strengthened by the conditions of development of the femoral tubercles throughout the series. We have a homogeneous group within which a new structure appears, reaches its climax, and then begins to retrograde. As regards most of the other characters, they have been found to be incipient in

tentoria, intermediate in *verreauxii*, and to reach their climax in *oculifera*; but, as regards the femoral tubercle, the climax is reached in *verreauxii*, and the tendency diminishes in importance towards *tentoria* on the one hand and *oculifera* on the other.

Elsewhere (*Records Albany Museum*, Vol. I., p. 409) allusion has been made to the fact that somewhat similar variations of the femoral tubercle occur in the tortoises of the South African genus *Homopus*. In the coast forms the spine is either wanting or very feebly developed, while in those far inland on the high, dry plateaux it is exceedingly well developed. We seem to have here another of those striking instances of the influence of like environment producing the same effect upon the members of two groups otherwise wholly unrelated (Homeoplasty).

The rows of enlarged circular shields found along the sides and dorsal surface of the tail represent a new character, which is practically restricted to the *verreauxii* sub-group, and even here is not always represented. They first appear, reach their climax, and as gradually disappear within the same sub-group. Their development evidently represents a response to the same tendency as that exhibited in the femoral shields; they probably protect this vulnerable part of the body, and the two reach their highest development in the same individuals.

II. 1. SPECIFIC TYPES.

Hitherto attention has been directed to the individual characteristics of the *geometrica*-group, their variations in the different sub-groups, and mode of transformation from one stage to another. It is manifest that the variations of any one character may serve as a complete study. In nature, however, we find all the characters associated in the individual, and it is the sum of these and other features which constitutes the organism. Hence to complete the study enquiry must be directed to the combination of the characteristics making up the individual.

As the various structures discussed are present at one developmental stage or another in each individual member of the *geometrica*-group, it is obvious that they offer great possibilities in the way of combinations, unless, indeed, one character can be shown to vary *pari passu* with all the others. Unless this latter condition is the rule, one or more characters may have progressed or retrograded in complexity while the remainder have continued unchanged, or all may have changed in different degrees; also a feature may be fixed and stable in one group while fluctuating in others. The evolutionary forces at work, whether internal or external, or both combined, may influence some structures and not others, or some to a greater degree than others, or even along different lines.

It is conceivable that within a restricted series of organisms like that of the *geometrica*-group, all the characters may vary together, in which case there would be just as many specific types produced as there are stages in the evolution of any one character.

But it is not probable that such regularity could be maintained. Even under similar external forces one would expect, as a result of germinal selection, that certain characters would be transformed at a different rate in some forms than in others, or in different directions. Much more likely are we to have variations if we consider the individuals placed under different environments, where the various features will respond differently; given time and isolation there seems scarcely any limit to the possibility of the production of different types, even with the comparatively few characters discussed.

A consideration of the origin of even such a limited number of forms as those constituting the *geometrica*-group opens up most of the great questions involved in the evolution of the specific type, and while a large number of the necessary facts are wanting, the data available seem to throw some light upon the processes involved. We have before us a group of organisms everywhere recognized as made up of members very closely allied, and, presumably, having a common genetic source, and many, with good reason, are already recognised as distinct species. It therefore seems worthy of enquiry as to how these specific types are constituted, and how they have been evolved or transformed within the limits of the group.

In any discussion of the nature of the specific type, the conclusions arrived at will largely depend upon the conception entertained as to the definition of species. In the present connection, the main point at issue is whether the extremes of a series of intergrading forms are to be regarded as species, or only as sub-species or varieties. The question will be more fully discussed later, but in the following account I have accepted the latter conception, believing that it more nearly represents the facts of nature, even if not so satisfactory for systematic uniformity and orderliness.

a. TESTUDO GEOMETRICA, Linneus, 1766.

The typical forms included under this name have their characters very clearly defined, and among them are many representing extreme modifications, when compared with those of other members of the group. Among the specific distinctions are: (1) the large, high shell, gradually sloping and narrowing in front; (2) the deep, downwardly directed, marginal shields, without or with only a feeble margino-costal angulation; (3) the long, narrow nuchal; (4) the five or six antebrachial shields, not overlapping. In all these *geometrica* has diverged from the other sub-groups, but in its coloration, both above and below, in the absence or rudimentary nature of the femoral tubercle, and in the long beak, it does not differ from certain of the other sub-groups. The shell attains a much larger size than in any of the others, one specimen having a length of 24 cm.

The combination of all the above characters makes *geometrica* a well-defined species, were it not for the possible presence of transitional types. Among the material available, these intermediate types are wanting, and for the present the question of the isolation

of the forms with the above characters must remain open. Such a position shows how relatively uncertain is the standing of a specific type. Taken by themselves, the members of *geometrica* would be accorded specific distinction by every systematist, but could we secure all the intermediate forms leading from the less specialized forms up to these extreme stages—stages which must certainly at one time have existed—they would be reduced to the rank of variety. It is hoped that a larger number of individuals from intermediate districts may yet be forthcoming.

b. TESTUDO OCULIFERA, Kuhl, 1820.

This species possesses the most distinctive features of all the members of the *geometrica*-group. Taken together, the assemblage of characters calls for specific recognition perhaps more strongly than any other combination; indeed, its specific rank has hitherto never been questioned. Only when the characters are taken individually, and traced through the various groups, can its close relationship with the others be established, and afford hope that it may be possible to secure a gradational series of forms presenting the same combination.

Compared with the remaining sub-groups, there are many extreme stages in the characters of *oculifera*. This is particularly the case as regards the elaborate coloration of the carapace and plastron, the single axillary shield, the large nuchal shield, and the serrations of the marginal plates; moreover, these features are all fairly constant and fixed.

Oculifera and *geometrica* are the only two forms in which there is the combination of a single axilliary shield and a practical absence of any margino-costal angulation. As already described, both of these conditions represent extreme variations, and might easily be interpreted as proving a close relationship between the two species. On account of the first character, Siebenrock, in his synopsis, places them together in a separate section, but Boulenger arranges the two at the extremes of the entire group. The other characters of *oculifera* and *geometrica* indicate that the two species are widely divergent, as such relationships go within the *geometrica*-group. Thus the condition of the antebrachial shields in the two sub-groups represents modifications along very different lines; the femoral tubercle is strongly developed in *oculifera*, but absent in many *geometrica;* the margin is strongly serrated and upturned in *oculifera*, smooth and dependent in *geometrica;* and the coloration is very different in the two.

Oculifera and *geometrica* afford remarkably good examples of variation along similar lines as regards certain characters, and along divergent lines as regards others. Such a condition probably points to a common origin far back before the characters in question were elaborated; from this the two have been transformed alike in certain directions, while they have diverged along others. On the theory of germinal selection we should assume that the determinants of

some characters have retained their ascendency in both sub-groups, while at the same time other and divergent determinants have become uppermost, maybe as a result of varying external conditions.

The two contrasted species are widely separated geographically. *Geometrica* is limited to the low districts around the south-western extremity of Cape Colony, whereas *oculifera* is found over a wide area, along the high, northern borders of Cape Colony, extending into Damaraland and the tropical parts of Bechuanaland.

There can be no question that *oculifera* is very closely related to the *verreauxii* sub-group, but the specimens at my command can scarcely be regarded as directly transitional where the combination of all the characters is taken into account. Until the intermediate region between those from which *verreauxii* and *oculifera* have been obtained is thoroughly explored, the form must be accorded specific rank. As in the case of *geometrica*, it is probably our present ignorance of transitional forms which forces one to this conclusion, and strong efforts are being made to remedy this.

c. TESTUDO TENTORIA, Bell, 1828.

The forms embraced under this species present great variations in all the characters under consideration. In many ways they come nearest to what we may suppose the common ancestor of the *geometrica*-group to have been; the characters are very fluctuating, and in almost every direction suggest conditions which are more elaborated elsewhere. When discussing the separate characters, the *tentoria* sub-group was in nearly every instance taken as the starting point, as representing the most generalized or incipient condition. Better than in any other sub-group, its different members suggest the lines of elaboration which the various characters will pursue.

Within this sub-group we find the transitions from the uniformly arranged radiating yellow rays on the carapace shields, all of equal value, to the distinction into primary, secondary, and tertiary rays; the transitions from the uniformly black, central patch and yellow sides of the plastron, to the rayed pattern; the transitions from the rows of uniformly enlarged antebrachial shields to the excessive growth of a more central one, and from the absence of an enlarged femoral spine to a strongly developed one; transitions from four or five inframarginal shields to only one; from an extremely knobbed carapace to one with almost flat shields; and from a rudimentary, incipient nuchal shield to one well developed.

The species has a wide geographical range, and, placing together suites of specimens from different localities, marked differences are recognizable; yet, when compared with the many transitional varieties, no one would dream of giving them specific rank. It is unquestionably a very plastic form in every respect, but with local assemblages showing more or less constancy.

The representatives occurring around the southern and eastern coasts are least specialized or furthest removed structurally from the other sub-groups, but as we approach the more inland and northern

parts of the colony, and also the western areas, modifications begin to be introduced, suggesting transitions to other well recognized sub-groups. Thus, from the Hex River, Worcester District, are to be obtained variations altogether intermediate between *tentoria* and *trimeni*, the latter sub-group having its headquarters further north in Namaqualand. These specimens already show the breaking-up of the black, central band of the plastron into rays, and the beginnings of a more definite arrangement of the yellow rays on the shields of the carapace, such as is characteristic of *trimeni* and others.

Fine examples of *tentoria* occur in the District of Beaufort West, which borders on the districts whence *verreauxii* are obtained, and in nearly all their characters they are transitional in the direction of *verreauxii*. Tracing all the individual variations in detail, comparing them on the one hand with typical *tentoria*, and on the other with typical *verreauxii*, one becomes deeply impressed with their intermediate nature. It would be scarcely possible to obtain better instances of gradational types than those presented by *tentoria* and *trimeni* on the one hand, and *tentoria* and *verreauxii* on the other, and, as shown in the next section, *trimeni* and *verreauxii* differ but little from one another.

d. TESTUDO VERREAUXII, Smith, 1839.

The forms which I include under this species present a great variety of characters, and several distinct species have already been established upon single individuals which unquestionably belong here. Fortunately, for the present study, a large number of specimens, about 150, are available, largely obtained from one locality, namely, the District of Hanover. This large collection I owe to the kindness of Mr. S. C. Cronwright Schreiner, M.L.A.

In very many of its characters *verreauxii* is intermediate between *tentoria* and *oculifera*. It is sufficient to turn to the discussion on the individual characters to see how frequently members of the sub-group are introduced to establish the transition from the extreme condition of *tentoria* to the opposite extreme in *oculifera*. The accessory femoral and caudal shields reach their maximum development in this species, but all the other characters are transitional. As regards the details of the coloration, scarcely any two specimens are alike, and almost any individual, if considered alone, could be made the type of a species. It is only where one can compare a large number side by side that the extreme lack of fixity of pattern becomes manifest.

In his paper, Siebenrock distinguishes this species by having the first costal greater than the fourth, and by having alternately yellow and liver red rays on the dorsal shields. The red rays he considers as the most distinguishing feature, as such do not occur in any other species of the *geometrica*-group. The seven specimens examined by Siebenrock are from Great Namaqualand and German South-West Africa, while Smith's original specimens came from near the sources of the Orange River. The type of coloration described by Siebenrock is not met with on any of the specimens studied by me, all of

which were secured much nearer the source of Smith's original specimens than those from German South-West Africa. In all the other details mentioned by Siebenrock there is nothing which is not to be found among the Hanover specimens. If the coloration given should prove to be a constant feature, it might mark a point of departure of the Namaqualand specimens from the original type as described by Smith.

Verreauxii evidently extends across the middle northern part of Cape Colony, probably all along both sides of the course of the Orange River into German South-West Africa. Its area of distribution is thus between *tentoria* to the south and *oculifera* to the north.

Taken by themselves, individuals of *verreauxii* would certainly be regarded as representing a distinct species of the *geometrica*-group, but, when we see how strictly transitional in every character are the more inland forms of *tentoria*, it is impossible to regard *verreauxii* as but a variety of the older species.

e. TESTUDO TRIMENI, Boulenger, 1886.

The forms included by Boulenger under this term possess what seem to be fairly fixed and constant characters, though decidedly transitional. The species was founded upon a number of specimens obtained by the Rev. G. H. R. Fisk from around the mouth of the Orange River, Namaqualand, and in the South African Museum are other specimens also collected by Mr. Fisk in this region. These specimens agree in nearly every particular with Boulenger's description and figures.

The coloration of the carapace in *trimeni* can be easily derived from that of *tentoria* or *verreauxii*, while that of the plastron, showing the early stages in ray development from the continuous middle black patch, is like that of some *tentoria* and *geometrica;* the absence or rudimentary nature of the femoral tubercle compares with other coast forms. The yellow spot or streak at the junction of two costal plates, considered to be of some diagnostic importance by Boulenger and Siebenrock, is a very frequent character in *verreauxii* and *geometrica*, and represents the rudiments of either secondary or tertiary rays; moreover, it is by no means a constant character in *trimeni*, for in most of my specimens it is either wanting or represented by a continuous secondary ray.

Compared with those of other sub-groups, the characters of *trimeni* are of a very generalized nature, there being no instance among them of extreme modification. They clearly exemplify how species may originate by the cessation of variation, for although none of the characters have reached the extremes they possess in *oculifera*, they appear already fixed and stable. Were the transitional forms to disappear, the combination of characters reached in *trimeni* would be well worthy of specific recognition, but with the gradations towards it from both *tentoria* and *verreauxii*, it cannot be regarded a distinct species in a strictly logical sense. Geographically, it borders on *verreauxii* and *tentoria*.

f. TESTUDO SMITHII, Boulenger, 1886.

Boulenger established this species in 1886 upon a single specimen with the rather indefinite locality "South Africa." He distinguishes it from *verreauxii* mainly by the presence of the large femoral tubercle, but as it is practically certain that *verreauxii* possessed these structures, the distinction can no longer hold, and there appears no other valid character which can separate them. Boulenger's figures of the upper and lower aspects of the shell present conditions frequently occurring within the *verreauxii* sub-group.

Siebenrock identifies four shells from Great Namaqualand as this species, distinguishing them from *verreauxii* by differences in coloration; in the latter yellow and red rays occur, while in *smithii* there are only yellow rays; differences in the relative sizes of the shields are also noted. None of these characters can be regarded as of specific value, now that we know how very variable are the members of the *geometrica*-group.

Neither Boulenger nor Siebenrock, in my opinion, produces characters which would serve to separate *smithii* from the many varietal forms of *verreauxii* obtained from a single locality; none of the characters are sufficiently definite to indicate a new type, or an extreme modification in any direction.

g. TESTUDO FISKII, Boulenger, 1886.

This is another species which Boulenger founded upon a single specimen. Fortunately, in this case the exact locality from which it was obtained, namely, De Aar, not far from Hopetown, is known. The District of Hanover, whence came one large collection of over a hundred *verreauxii*, includes the town of De Aar, and I have also secured, through Mr. Cronwright Schreiner, 20 specimens from De Aar itself. Among them are many exactly corresponding with the description and figures given by Boulenger, so there can be no question of the correct identification; for a long time I regarded all my forms from Hanover as *fiskii*, but further study leaves no doubt that *verreauxii* was the name originally given to this type of the *geometrica*-group.

The color pattern in *fiskii* is certainly a very distinctive feature when taken by itself on any single specimen, but when it is stated that among 150 specimens there are no two specimens exactly alike in this respect, it is seen how comparatively unimportant is the feature. With the single specimen before him, and the few related types for comparison, it will be admitted that no other course was open to Boulenger than to describe the type provisionally as a new species; now, however, when an abundance of specimens from the same locality is available, we can better appreciate the value to be placed upon many of the characters hitherto utilized for specific purposes. For his studies on the four species—*verreauxii*, *smithii*, *fiskii*, and *seimundi*—Boulenger had only three specimens, and Smith's description of the first; the *verreauxii* of Smith was retained, and

each of the other specimens was made the type of a new species. It is now seen that Smith's species is sufficiently variable to include them all.

h. TESTUDO STRAUCHI, van Lidth de Jeude, 1893.

This species was founded by Dr. T. W. van Lidth de Jeude (*Notes from the Leyden Museum*, Vol. XV., 1903) for a single specimen of tortoise found in the Leyden Museum, "collected at the Cape of Good Hope by the late Kuhl and van Hasselt." Its author considers it to have much in common with *T. gometrica*, but differing in the absence of the nuchal shield and the elongated form of the gulars. Comparing the figures and rather brief description with the several forms of *geometrica* in my possession, it is evident that the Leyden specimen is a true *geometrica*, except for the absence of the nuchal shield. In my examples this shield has become so very narrow that it is easy to conceive how it may disappear altogether in individual specimens. Everywhere the relative size of the gulars is found to be so very variable that the establishment of its absence in many specimens would be necessary before it could be regarded as a distinguishing specific character.

Further collections will certainly be necessary before the specific recognition of *strauchi* is assured. Even if a group of forms devoid of the nuchal should be forthcoming, it would still be a matter of dispute whether the character is sufficient to warrant the members being regarded as distinct from *geometrica*. In the present paper I can only regard *strauchi* as a form of *geometrica* in which the nuchal is wanting.

i. TESTUDO SEIMUNDI, Boulenger, 1903.

This species was established by Boulenger for a single specimen picked up near Deelfontein, in the District of Richmond. The district is adjacent to the District of Hanover, whence, as already stated, I have secured about 150 specimens, all belonging to the *verreauxii* sub-group. Compared with these, *seimundi* has no distinguishing characters whatever, and unquestionably it belongs to the same sub-group. The strong grooving of the marginals, the incurved supracaudal, and the size and shape of the gulars have their exact counterparts in the Hanover specimens. The yellowish brown horn colour above, in contrast with the black background, occupies more superficial area than usual, but introduces no new feature. The shells of older specimens frequently reach this stage. The plastral coloration compares even more closely with other members of the *verreauxii* sub-group.

Now that we know the variations of the *verreauxii* sub-group much better, it is clear that *seimundi* cannot be retained as a distinct species. Moreover, there is nothing in all the characters given which indicates that it represents the beginning of even a new type or variety; with the exception of the dominance of the yellow colour

of the carapace, there is nothing to distinguish it from an ordinary member of the *verreauxii* sub-group. Siebenrock (p. 308) has also expressed the opinion that, judging from Boulenger's figure and description, the species is much nearer *verreauxii* than *tentoria.*

j. TESTUDO BOETTGERI, Siebenrock, 1904.

This is a species lately founded by Siebenrock for a single shell from Greater Namaqualand, Boettger having previously determined it as *T. smithii.* The latter considered the habit of the shell to ally it with *smithii*, but the colour of the upper surface to be different; Siebenrock holds that the coloration is most nearly allied to that of *trimeni*, only there is wanting the small, yellow spot at the junction of adjacent costal plates shown in Boulenger's figure of *trimeni.* According to Siebenrock also, its habit brings it nearest to *smithii*, but the upper surface of the shell is flatter, particularly in the vertebral region; the chief difference, however, lies in the comparative sizes of the plastral shields, the gulars being much longer than in *smithii* and *verreauxii.* The relative proportions between the free portion of the margin of the carapace and that united with the bridge are also different from usual. The black spots on the areola employed by Siebenrock as an important diagnostic feature for this and other species are very inconstant in specimens of *verreauxii* from the same locality.

From all this it is evident that *boettgeri* has no definite characteristics, constant in nature, which serve to separate it from the variable sub-group which includes *trimeni*, *smithii*, *fiskii*, and *verreauxii;* moreover, the shell was obtained from the area whence *trimeni* was first obtained.

2. DISCUSSION.

a. NUMBER OF SPECIES REPRESENTED.

The foregoing account fully establishes that we have in the *geometrica*-group of tortoises a remarkable series of allied forms, including a certain number which may be considered as extreme types, with fairly fixed characteristics, connected by a large number of intermediate forms with variable characteristics. It must be acknowledged that if the members of the extreme types only were known there would be no hesitancy in according them full specific rank. Ever since their discovery no one has questioned the true specific value of the forms embraced under *geometrica*, *oculifera*, *tentoria*, and *verreauxii*, and it is only the acquisition of a large number of related individuals which renders their standing doubtful. As regards the other species, I am of opinion, now the degree of variation is better known, that reliable, distinguishable characters are not available; founded, as they were, mostly upon single specimens, it was impossible at the time to determine the true taxonomic value of the characters presented. The conclusion may be stated in another

way. I am convinced that if all the tortoises belonging to the *geometrica*-group at present living in South Africa could be gathered together no sharp distinction would be found between the extremes; there would be an almost imperceptible passage from one so-called species to another; there would be numerous specimens, of which it would be impossible to say to which of two species they should belong.

In any discussion of specific types, the conclusions reached will depend much upon the conception entertained of the term species. If we consider a species to include a group of individuals having certain distinct characters in common, and find that they breed true to these characters, and continue to do so, then we must recognize a large number of species within the *geometrica*-group; for almost each locality has its group of individuals which differ from others in features which might fairly be considered as constant. With such slow breeding creatures as tortoises it would be difficult to prove this experimentally, yet there can be little hesitation in holding that such as *oculifera*, *tentoria*, *verreauxii*, *trimeni* and *geometrica* would breed true.

When, however, we find that these groups are connected with one another by transitional forms the above conception of a species is insufficient. Probably the clearest expression upon the bearing of transitional forms on taxonomy is that recently given by Ortmann (Science, May 11th, 1906): 'Of course, it is generally admitted that species should breed true; but this is also a necessary character that belongs to the concept of variety. What distinguishes species from varieties is the fact that a species is not connected by intermediate or transitional forms with the most closely allied forms. This latter principle is the one made use of exclusively (if possible) by systematists, botanists as well as zoologists. In many cases, indeed, it cannot be used on account of the insufficiency of our knowledge, but under such conditions new species are always described with the tacit understanding that the demonstration of the existence of intermediate forms will reduce them to the rank of varieties.'

The theory of evolution by gradual modification implies that all living organisms are genetically related, having had ancestors in common. Were all these available for study there would be no such cleavages as those involved in the concept of species. It is the missing of the chain, the extinction of intermediate forms, which [illegible] us species. The concept of species implies that a number of individuals have sufficiently distinct and constant characters to separate them from their relatives, the transitional forms originally connecting them and these nearest relatives being no longer existent.

From this point of view, the results of the discussion upon the taxonomic standing of the ten different species of the *geometrica*-group may be summarized as follows: Both *oculifera* and *geometrica* have numerous, well-defined, distinguishing characters, many of which represent extreme variations of features transitional in others. Regarded as combinations of characters, the two must for the present

Geometrica is the form found in the extreme south-western part of Cape Colony, in the Cape and Malmesbury Districts. Its extension requires further investigation, but cannot be very wide.

Trimeni is found along the coasts to the north of *geometrica*, along each side of the mouth of the Orange River, that is, in Namaqualand and German South-West Africa.

Verreauxii has a very wide inland distribution, extending almost across the southern part of South Africa, from Basutoland on the east to German South-West Africa on the west. Within this area have been obtained *smithii*, *fiskii*, *seimundi*, and *boettgeri*.

Oculifera occurs to the north of the zone of *verreauxii*, having been obtained from Barkly West, Griqualand, Bechuanaland, and Damaraland.

Thus each well-defined type of the *geometrica*-group occupies a very distinct geographical area in South Africa, the elevation and other physiographic conditions of which vary considerably. If one were able to study the peculiarities of the environment closely there is little question that the variations would be found to be largely adaptive, but the study of this aspect of the subject has not yet been possible. Even if the adaptive nature of the variations were established, it would not follow that the variations have been made by the environment; there seems much more evidence for the view that the transformations are primarily a manifestation of qualities inherent in the constitution of the organisms themselves—endonomic selection.

In a short paper on the South African tortoises of the genus *Homopus (Records of the Albany Museum*, Vol. I., p. 410), I have shown that the six species of this genus have likewise a very restricted distribution, coinciding in some ways with that of the members of the *geometrica*-group.

In contrast with the restricted distribution of the representatives of these two groups is the wide extent covered by two other species of South African tortoises, *Testudo pardalis* and *Testudo angulata*. In their general appearance these two are very different from one another, and also from the species of *Homopus* and the allies of *T. geometrica*. Any common origin must be far removed. Both species are plentiful, and apparently extend all over South Africa. *Pardalis* reaches to East Central Africa, and, along with *angulata*, is found in Natal; no local variations of any importance have been observed. It is very significant of the constitutional differences among organisms when one reflects that these two forms are to be found all over South Africa, without any important variations, while species of *Homopus* and the *geometrica* allies are highly distinctive of special divisions of this area. Evidently the members of the *Homopus* and *geometrica*-groups have been, and probably still are, in a more variable or plastic state than *pardalis* and *angulata*; the first two groups are in process of transformation under South African conditions, while the others seem fixed. Of the two, *Homopus* is at present much less variable than the *geometrica* series, as no intergrading forms among its recognized species have yet been found.

c. ORIGINAL TYPE OF THE GEOMETRICA-GROUP.

It is impossible to say with certainty which of the described forms of the *geometrica*-group is nearest the original type from which the others may be supposed to have originated. In any ancient group we are not likely to obtain the primary type still living for, on the theory of evolution, it may have been lost in giving rise to new types. In modern groups it is more probable that the primary type is still living on, perhaps unchanged, in the ancestral home, while others, radiating, have been subjected to new environmental forces, and transformed along peculiar directions.

If we think of any type of the *geometrica*-group having the most generalized characters from which the others may have evolved in different directions, *tentoria* most nearly fulfils these requirements. In this sub-group are gathered together, in more or less incipient stages, all the characteristics which become elaborated to make up the many types of the *geometrica*-group as we know them. The knobbed form of the dorsal shields is the only character which presents an extreme variation in this sub-group, but in practically all its other features the sub-group has been taken as the starting point for characters elsewhere more pronounced.

If we desire an original type, around which all the divergent forms centre, then the *verreauxii* sub-group most nearly conforms to such. Taking the stages of the various characters, it is easy to see how by variation in one direction we may get such an extreme as the *oculifera* type, and, by variation in an opposite direction, we may reach the *tentoria* type, or the *trimeni*, and, much more remotely, the *geometrica* type.

The most logical course is unquestionably that which regårds the *tentoria* type as the original, for from the variational tendencies represented within the sub-group itself, we can readily conceive how all the different combinations have arisen.

On the understanding that all these types have originated from some common ancestor, it may reasonably be asked why have not all the forms been transformed; why have some retained a simple condition in certain of their characters while others have gone on developing? Why have we *oculifera*, *tentoria*, and *geometrica*, representing very different stages of evolution, almost equally abundant at the same time? If the variations of the group were due to some simple internal force within the organism itself, we should have expected that practically the same level would have been reached by all at the same time, and that the original type would have disappeared in the latter transformations. But this is not the case. Germinal selection as a complex force may possibly have sufficed to produce such varieties, one series of determinants obtaining the upper-hand in one place, and others elsewhere.

Though the internal processes in the germ plasm might well have run a different course in different, separated colonies, yet it is much more probable that the explanation of the condition of affairs as we

find them to-day is to be sought in germinal variation under the selective influence of environmental changes. The study of their geographical distribution shows that different types occupy different areas, and there is some evidence that certain of the characters are selective as regards these different environments. I am therefore of opinion that the explanation of the present conditions is to be found in germinal variations along determinate lines, influenced by environmental forces. Given variation along definite lines, then adjustment to environment is to my mind the key to the occurrence of different forms in different districts.

III. SUMMARY.

1. Ten species of the *geometrica*-group of South African tortoises have been described by different systematists. In the present paper attention has been directed, first, to an analysis of the variations of the separate characters which are relied upon in describing the species, and, second, to the associations and combinations of the variations in the individual, involving the production of specific types.

2. With certain exceptions, all the characters discussed are present at one varietal stage or another in all the individuals. The general uniformity of the characters is taken as proof of the homogeneity and recent differentiation of the *geometrica*-group, and evolution consists in the gradual elaboration of characters traceable throughout the group.

3. Certain characters are wanting or incipient at one extreme, e.g., the femoral tubercle; certain new characters are restricted to what may be considered as intermediate members of the group, e.g., supplementary femoral shields, rows of caudal shields. These new characters are to be regarded as but further expressions of tendencies already indicated by other characters.

4. All the characters present a gradual change in complexity or elaboration, passing uninterruptedly from what we may consider as one extreme to the other. They afford proof of Continuous or Determinate Variation (Orthogenesis). There is no evidence of any rapid or sudden change from one condition to another, nor the sudden introduction of new characters: Discontinuous or Indeterminate Variation (Mutations). The transformation of any one character may be in only one direction or in more than one.

5. Certain characters are very fluctuating in some sub-groups, and constant in others. The former condition may be taken as indicative of the activity of the processes of germinal variation, perhaps associated with environmental changes, and is conducive to the establishment of new types; the latter state as indicative of a cessation of germinal variation and constancy of environment, and not conducive to the production of new forms.

6. In the production of the specific type, it is found that the stages reached in the transformation of different characters either differ in the same individual (non-correlated variation) or vary *pari*

passu with one another (correlated variation). In the former the individuals possess extreme and transitional stages or transitional stages of different degrees, in the latter they are either all extreme or all transitional stages.

7. Each varietal type has a restricted geographical distribution, without overlapping; and the more nearly related types occupy adjacent areas. Compared with other South African tortoises, it is found that each species of the genus *Homopus* has a restricted distribution, with characters showing little variation, while *T. pardalis* and *T. angulata* are widely distributed, also with slight variability.

8. Among the ten described species of the *geometrica*-group, only three distinct types of combination are recognizable: *oculifera, geometrica,* and *tentoria*. These may for the present be considered as sufficiently separated from any transitional forms to be given specific rank, and *tentoria* presents at least three well marked varieties or sub-species: *tentoria (sensu strictu), verreauxii,* and *trimeni*. Four of the other described species *(smithii, fiskii, seimundi, boettgeri)* are not sufficiently distinct from the fluctuations of *tentoria* to warrant even varietal recognition, while *strauchi* may be a variety of *geometrica*.

16—DEATH-FEIGNING INSTINCT IN THE OSTRICH.

By J. E. Duerden, Ph.D., A.R.C.S.

Professor of Zoology, Rhodes University College, Grahamstown.

Justly or unjustly the ostrich has become proverbial for stupidity. Both in literature and conversation the bird is frequently referred to as representing the extreme of foolishness from its supposed habit of hiding its head when alarmed, and leaving the rest of its body exposed to observation and danger. It must be understood that in applying such terms to an animal's behaviour we are, without warrant, presupposing consciousness and passing the same judgments upon it that we would upon the actions of an intelligent human being. Perhaps an enquiry into the actual habits of the ostrich and their underlying significance may serve to shed some light upon the justification or otherwise for the doubtful mentality usually accorded the bird. One generally discovers there is some foundation of fact in the habits of creatures or persons which have become bywords, though it is often found that in the first and superficial impressions the true significance of the phenomenon has been missed.

All ostrich breeders are aware that if ostrich chicks, while only a few days or weeks old, are suddenly startled they will at once crouch down, as if dead, and remain thus for some time. The action is much more likely to occur if the chicks have been hatched and reared out on the veld, away from human influence. An actual personal experience will best illustrate what happens. Driving over an ostrich farm one day a pair of ostriches were come upon, surrounded by a dozen or so chicks about a week old; the chicks had been hatched out on the open, and no personal attention given them. Dismounting from the cart, a sudden, clamorous rush was made towards the group, when the parent birds at once ran away and the chicks scattered and disappeared so suddenly and so completely that for the moment one knew not which way to turn in order to follow them. After remaining quiet for a few moments, and getting the eye accustomed to the surroundings, it was found that several chicks were lying quite near, so that one might almost have stepped upon them. Their bodies were prone upon the ground, with the neck and head stretched out resting upon the surface. The resemblance of the mottled black and brown bodies of the chicks to the rocky ground and scant vegetation was so perfect that it was with much difficulty the various individuals were discovered.

The recumbent chicks allowed themselves to be approached and picked up, when they were found to be quite limp and motionless, appearing altogether lifeless, and only recovered after being conveyed for some distance.

This behaviour on the part of the ostrich chick is a clear and striking instance of death-feigning or death-shamming. In this state the animal appears and acts as if dead, and, thinking of it in terms of human actions, we explain it as if consciously assumed for the purpose of deceiving its enemies. The same instinct is also well developed in many birds (rails, bustards), mammals (opossum, jackals, foxes), and especially in insects.

From the behaviour of the ostrich chicks it may be assumed that on rushing towards them the first instinct to assert itself was that of flight, and the birds scattered. Then extreme fright or terror supervened, and brought about a general nervous collapse of the chick, as a result of which it flopped down. From this condition of nervous collapse it only slowly recovered. In insects, as, for instance, in many beetles, it is often found that a sudden touch will bring about the same response, though it is very questionable as to how far what we know as fear is here concerned. It seems to be little more than a reflex reaction which has proved itself useful to the animal's ancestors, and thereby been preserved and more perfectly developed by natural selection.

Death-feigning in the ostrich chick has evidently a greater significance than that of merely giving to the animal the appearance of being dead and inert, in the same manner as in an insect. The principle of protective resemblance is also involved. Every ostrich farmer knows the extreme difficulty of finding a brood of ostrich chicks once they scatter in the bush and crouch down. After a prolonged search he will secure only a few of those immediately near him, and then return for a second attempt, when the birds have again gathered round the parents. The peculiar black and brown striping of the neck, found only in chicks, and the mottled black and brown natal plumage harmonize most closely with the surroundings when the chicks are recumbent upon the ground.

The chicks appear to get beyond the instinct of death-shamming very early. The ones just mentioned never again displayed the reaction after being brought home and reared by hand; and it seems to be rarely resorted to by incubated chicks artificially reared. Under some circumstances, however, very young birds, say to one month old, will fall flat from almost any object or noise which suddenly startles them, and this applies to tame chicks as well as to wild or nearly wild ones. Also as the chicks get older the collapse is not so complete nor does it continue for so long a period as at first; for frequently after a bird has crouched down and one makes towards it, the creature will spring up and make off, perhaps to drop a second time if hard pressed. The experience of farmers is that by the time the chicks are a month or more old they resort more freely to running when alarmed, and only crouch when hard pressed or very suddenly startled.

We may now consider if there is any evidence for the instinct being continued into the adult stage of the ostrich. In a general way it is found that when an ostrich is alarmed it takes to running. and even the fleetest horse is incapable of keeping pace with it so long as the pursued continues in a straight course. Once fully started, the bird probably never has recourse to the true death-shamming instinct, but will continue its course as long as its strength lasts, and only fall flat when exhausted, often never to rise again. In the days of wild ostrich hunting the birds were thus frequently driven to death with a horse. The instinct of flight, however, is not resorted to under all circumstances by adult birds. Instances are

known where an adult ostrich has been come upon quite suddenly, as from the top of a kopje, and the bird was apparently so startled by the apparition that it at once collapsed on the ground with its neck and head outstretched, and made no attempt to escape. The primary instinct of death-feigning was here the first to assert itself, not that of escape.

Mr. Guy A. K. Marshall has observed the habits of the wild ostrich in Mashonaland, and states that in one case the bird squatted after running for some considerable distance and dodging about among some low bushes. In a second instance, coming suddenly over a rise in quite open country, three ostriches were seen about 400 yards away. They detected the intruder at once and dropped like stones, being then almost indistinguishable from the ant heaps among which they were feeding. Upon continuing to walk towards them, they evidently recovered from their collapse, rose up, and soon made off out of sight.

Such well-authenticated observations prove conclusively that the ostrich may retain its instinct of death-feigning into the adult state; it is not resorted to so freely as when the bird is young, but it still comes into action under certain conditions. The circumstances calling it forth seem to be sudden or intense alarm or fear. Under ordinary conditions of alarm the birds take to flight, but when suddenly alarmed, without perhaps a chance to escape, they follow an instinct which is more usual in the young. It is easy to understand the advantage gained by this gradual change of response. While very young the chicks would scarcely be able to escape an enemy by running, and hence death-feigning is an advantage to them, and is the usual procedure on alarm; as they become stronger and fleeter their increased bulk would result in exposure and danger, and thus they resort almost entirely to flight.

It is manifest that the ostrich has, as it were, a choice of actions when alarmed: either it can drop down and rely upon its inertness and close resemblance to its surroundings for protection, or it may take to running and depend upon its fleetness for escape. It is more likely to follow the former while young, the latter as it grows older. It may even act differently under what seem to be similar circumstances. As in many animals, particularly those higher in the scale, there is an element of uncertainty as to which of several possible courses may be chosen in an emergency.

An instinct which seems very closely related to the above is sometimes displayed by brooding or nesting birds. In this parental duty the cock and hen occupy the nest alternately, the hen mostly by day and the cock by night; to be somewhat accurate, the hen sits from 8 or 9 a.m. to about 4 p.m., and the cock from 4 p.m. to 8 or 9 a.m. The greyish colour of the female bird usually harmonises very closely with the natural surroundings by day and the blackness of the male by night. There can be little question that these sexual differences are the results of natural selection. Under ordinary circumstances the wild or semi-wild ostrich will sit with its long neck erect as if on the look out, but immediately it espies any danger, as

on the approach of man, down drops its neck and head flat on the ground, and it is with difficulty the position of the nest and bird can be detected. Often when searching for their nests the farmer finds it necessary to hide behind a distant kopje or rise, and locate the birds with their heads erect by means of a field-glass.

In studying the behaviour of animals we have to guard against attributing intelligence or even consciousness to all their actions. We see, as in the present instance, ostrich chicks acting in a manner which is obviously the one best adapted to the special conditions, but, although at first sight tempted to do so, no one would think of associating intelligence with the response, much less could we accuse the creatures of intentional deceit as is implied in the term death-shamming. Death-shamming is a congenital or hereditary act on the part of ostrich chicks; it is a complex action performed without any previous experience and independent of instruction. One can never be quite certain what are the factors, conscious or otherwise, which determine any action of an ostrich without becoming an ostrich one's self, nor altogether analyze its feelings unless one has the feelings of an ostrich; but we are probably safe in saying that the reaction is an altogether unconscious one and without any psychical attributes.

It is the exhibition of the instinct of death-feigning which has probably given rise to the stories of the ostrich hiding its head when in danger, and leaving the rest of its body exposed; and the tendency to put human constructions upon the actions of the lower animals has engendered the idea of stupidity as associated with the act. In a state of nature the act would be unquestionably useful both to the chick and the adult bird as a protection from its enemies. To the early ostrich hunters it must have seemed the height of stupidity, looked at from a human aspect, for such a large bird when alarmed to suddenly flop down before him limp and motionless, and with time the act has become a byword. But when we realise that this same instinct is undoubtedly useful under natural conditions we see that it has a deep significance, and can understand how in the past it may have been encouraged by natural selection.

To say that the ostrich hides its head and then believes itself safe is only an anthropomorphic way of interpreting the behaviour of the bird. It is probably an unconscious and involuntary act on the part of the creature just as much as is the collapse of a highly-sensitive person upon sudden fear. The hiding of the head is not an essential part of the act of death-feigning, but results from the well-known fact that the ostrich habitually crouches with its neck and head resting on the ground, thereby assuming the closest resemblance to its surroundings. The stupidity lies in our attempt at an explanation of the act, and not in the bird itself.

17—GEOGRAPHY AS A FACTOR IN HIGHER EDUCATION.

By Frank Flowers, C.E., F.R.A.S., F.R.G.S.

[ABSTRACT.]

The object of the paper was simply to endeavour to arouse an interest in the claims that Geography has for admission in the curricula of our Colleges and a place in the University Examinations; of course, in the sphere of Higher Education.

Educationalists might be of opinion that the paper embraced extravagant views and claims, but when the well-nigh total neglect that Geography in its pure form in class work has sustained is remembered, the almost hysterical announcements of Geographers are not to be wondered at. To quote from an article in the *Star*, commenting upon the fact that Geography is only compulsory in the School Elementary Cape University Examinations, that paper observes, "that is to say, the official opinion of the Chief Educational Institution in South Africa is that Geography is a study neither suitable nor necessary for boys above the age of 12."

The paper under review deals with the difficulties in framing an entirely satisfactory syllabus for Geographical study, owing, of course, to the manifold branches of the subject. It also suggests as a comprehensive definition or central theory for a working hypothesis that—Geography is the Science which details the Earth's dictation to Life.

The author quotes freely from prominent writers, such as Dr. Mill, Dr. Herbertson, Sir Clement R. Markham and others. Three are worthy of repetition.

Sir Clement points out that Geographical ignorance—speaking of Geography in its broadest sense—" is the cause of loss in commerce, of disaster in war, and blunders in administration. Until merchants, soldiers, seamen, engineers, lawyers, and above all, statesmen, are also Geographers, these evils will continue." Dr. Herbertson remarks: "Surely it is only common sense to see that it is properly studied by those who will direct great enterprise. When its educational and practical value are both taken into account, only ignorance or inertia or the influence of vested interests can explain its omission from the higher classes of schools, or from the Universities." While Dr. Mill directs attention to the fact that the glory of Geography as a science, its fascination as a study, and value in practical affairs arise from the recognition of the unifying influence of surface reliefs in controlling the incident of every mobile distribution of the Earth's surface; and that the grand problem of all must be the demonstration and quantitative proof of the control exercised by the forms of the Earth's crust upon the

distribution of everything which is free to move or be moved; that is to say, the physical conditions of environment to organise response.

After discussing Geographical education in the Transvaal, the writer closes his paper by expressing a hope that Geography in some co-ordinated form will soon find a place in our educational institutions, which becomes a positive necessity if the dream for South Africa's future is to be realised, and the rising generation, with Mr. Julius Jeppe, is to "look forward to a dawn of prosperity such as South Africa has never seen, a prosperity which will distribute its beneficial effects in ever-widening circle to the utmost bounds of civilisation."

18.—ON SOME ASPECTS IN THE VEGETATION OF SOUTH AFRICA WHICH ARE DUE TO THE PREVAILING WINDS.

By R. Marloth, Ph.D., M.A.

In tracing the relations between the climate of a country and its vegetation, it is often thought sufficient to discuss the temperature, i.e., the mean for the year or the months with the extremes of heat and cold, and the rainfall, viz., its total amount and the distribution over the different seasons. One calls the climate of Eastern South Africa the reverse of that of the West simply because their rainy seasons are opposite to each other.

It is, consequently, often overlooked, that climate with regard to vegetation includes several other factors, which have a considerable influence on the structure and aspect of plants, and that some of these are capable of modifying the effect of the two principal constituents of the climate to a large extent. One of these important factors is the relative humidity of the air, which does not necessarily go parallel to the rainfall. Further, the annual and daily amount of sunshine, for light is as necessary to the living plant as heat and water. One of the reasons why many Cape plants do not thrive in English conservatories is the curtailing of the supply of light to which they are accustomed.

Quite as important, however, as these factors, is the wind, if it does not even exceed their influence considerably.

The various ways in which the wind affects the vegetation of South Africa may be grouped under three heads:—

1. Mechanical effects.
2. The exhausting action, which it exerts on the leaves and growing points of plants.
3. The supplying of moisture to the vegetation of some of our mountains by means of the clouds which accompany certain kinds of wind.

Everybody is familiar with the shorn shrubs and dwarf trees along the seashore. The wind, often charged with salt spray or sand, destroys every leaf or twig, which projects above the sheltering rocks, and gives a slanting face to the top of the shrubs on the windward side. On the shores of False Bay, and even a mile or two inland, such wedge-shaped bushes are very common; but, of course, also everywhere else along the coast right up to Algoa Bay and East London. Some of them are as sharply defined as if they had been kept constantly under the gardener's scissors.

In other cases the pressure of the wind has forced the trees over to leeward. One may see whole rows of pines or eucalypts at Salt River and other equally windy places, which are leaning over to a considerable extent. Even groves of silver trees exhibit occasionally the same phenomenon, and in the coastbelt near East London stand thousands of dwarfed mimosa trees leaning over in the same direction, with a crown that is as flat as a table, all branches having been shorn down to the same plane by the sea wind.

The exhausting and destructive effect, which strong winds exert on the leaves of plants, is well seen after a South-East storm. The oaks and other soft-leaved plants look as if they had been scorched on the weather side. This is due to the enormous increase in the transpiration of the leaves, produced by the air which rushes past their surface with great velocity. As the supply of water from the roots cannot replace the loss with sufficient speed, the cells of the leaves are killed and the leaves dry up. Many introduced shrubs and trees suffer in a similar way, and many kinds cannot be reared in exposed situations, as e.g., chestnuts and horse-chestnuts, but do thrive in sheltered nooks and valleys.

Quite different is the appearance of the indigenous trees of the Cape, even after the severest storm. While oaks are scorched, and even eucalypts and pepper trees (*Schinus molle*) seriously damaged, the olives and proteas show no sign of injury to their foliage. Much less do this the hundreds of smaller shrubs and shrublets, which form the plant covering of the South-Western districts. The explanation is simple. Their leaves are of tough and leathery texture, they are trained to such extreme conditions; in fact, the wind has, to some extent at least, been instrumental in gradually producing them by a kind of natural selection. Almost all shrubby plants of the South-Western districts possess such leathery leaves, hence this part of South Africa is designated by ecologists as one of the typical regions of sclerophyllous plants.

It must not be thought that the wind is the only cause of this special feature in our vegetation, but it has certainly had a considerable share in its production.

The influence of this action of the wind is even more conspicuous in other cases. In localities, which are regularly exposed to strong winds from the same direction, one finds the trees often without branches on the weather side. Near Cape Town there are many pines on the slopes of the Devil's Peak with a perfectly straight and vertical stem, but bare on the Southern and South-Eastern sides. This flagstaff-like appearance is not caused by the removal of the branches on this side, but by the destructive effect, which the wind has on the soft tissue of the buds in spring. Only the terminal shoot and those on the leeward side are allowed to develop, while the others are destroyed as soon as they show themselves.

While the effects of wind described so far are not specifically South African, as many other countries exhibit the same or similar phenomena, there is one feature of the wind that prevails over a large part of South Africa during the summer months, which has no where else such a preponderating influence on the vegetation. That is the cloud covering of many of our mountains which generally accompanies the South and South-East winds and which supplies a considerable amount of moisture to the vegetation of the mountains during the season, which is otherwise dry. It is this property of the South-East wind which must be looked upon as one of the chief agents in the delimitation of the area or areas of that famous vegetation of the

PINE ON THE SLOPES OF THE DEVIL'S PEAK [*Photo by E. Dyke.*

South-Western districts, known to the botanical geographer as the Cape-Flora.

In the extreme South and South-West, where the winter rains are constant and regular, the valleys and plains are covered with proteas, heaths and Restionaceae, but North of the Langebergen these plants do not occur in the lower regions, being confined entirely to the mountains. The reason is a twofold one, for this remarkable distribution of the plants is partly due to the nature of the rocks; the mountains consisting of sandstone and the plains and hills mostly of shales; but principally it is caused by the clouds which supply moisture to the plants of the mountains, but not to the valleys or the hills.

On the Zwartebergen, the Anysberg, Touwsberg, the Kamanassi mountains, the Wittebergen near Matjesfontein, and a number of others, the line of demarcation between the karroid vegetation of the hills and the Cape-Flora is always well defined, for there is no mixing of the two formations. But even on the Cape Peninsula the contrast between the region of the clouds and the lower slopes is most remarkable. Many of the most famous flowers of the Cape are confined to the mountains, where the summer climate is so largely modified by the moisture-bearing clouds. The *Disa uniflora*, more justly called *D. grandiflora*, for specimens with 2 or 3 blooms are not uncommon, the blue *Disa graminifolia*, also known as *Herschelia coelestis*, the beautiful *Disa longicornu* and *D. ferruginea*, and many other orchids, do not descend below the region of the clouds. The gorgeous *Nerine sarniensis*, the *Anemone capensis*, *Watsonia Meriana*, and many beautiful heaths are confined to the heights, and the Cape cedar of the cedar mountains thrives at its best only above the 3000 feet level, where the winter brings more rain and the summer the clouds. There are hundreds, probably thousands, of species of plants which are dependent on this source of supply, and cannot exist where it fails, but it would be impossible to deal with them here.

How considerable the quantity of water is, which the South-East clouds bring, and which, it must be remembered, is not indicated by our rain gauges, was well demonstrated during a five-days' South-East storm in February, 1905, when the top of Table Mountain was transformed into a swamp, as if it were midwinter, although not a quarter of an inch of rain had fallen during a period of three weeks.

The area over which the South-East clouds extend is very considerable, for it reaches from Cape Point to the Bokkeveld and the Kamiesbergen in the North, and to the mountains of Uitenhage in the East, occasionally even to others further East and North. But the plants referred to above as some of the chief elements of the Cape-Flora, cannot thrive where the winter is dry, hence, being dependent on the rain of the winter months, and an intermittent supply of moisture in summer, they are hemmed in from East and North, and form a floral region of their own in a territory so small that it has no parallel in other parts of the world.

19.—THE NEGRO IN AMERICA.

By T. Lane Carter.

[Abstract.]

The first African slaves were taken to the New World by the Spaniards to work the gold and silver mines, as the Red Men had proved utter failures as labourers. Eventually the British excelled the Spaniards as slave dealers. The important part played by Great Britain in the introduction and spread of slavery in America was forgotten during the 19th Century, when the children of the men who had done so much to introduce negro slavery vehemently denounced the South for this institution. The British Parliament watched with zealous care the interests of the slave trade; slaves were forced on the Colonists for years after they cried out against the institution.

It should be remembered that the Civil War was not fought to liberate the slaves. No man in America dreamed of final emancipation, when hostilities commenced in 1860. Lincoln's Inaugural Address contains the declaration that "he had no purpose, directly or indirectly, to interfere with the institution of slavery in the States where it exists." At first Lincoln leaned to gradual emancipation, and as the war dragged on, he conceived the idea of doing away with the institution of slavery, which had brought such misery on the country. On January 1st, 1863, he signed the final Edict of Freedom. When the war came to an end there were four millions of freedmen in the South. The ex-slaves were entirely ignorant, untrained as a rule, save for servile occupations. Childlike in mind and habits, they interpreted their new liberty to mean release from restraint. In 1865 they began to wander away from the plantations, to enjoy the delights of idleness, to indulge thievish and immoral propensities to the full, and to work no more and no longer than they found agreeable. The dominant party at the North, the Republican, never rested until the whites of the South, the ex-Confederates, were disfranchised, and the negroes were enfranchised.

After the Civil War the victors did everything in their power to lift up the ex-slaves, and to debase and humiliate their own race living in the South. Wholesale confiscation of the Southerners' property was carried out in every State, and the lower class of politicians from the North (the "carpet baggers") promised the negroes "forty acres and a mule" for their votes. Red and blue pegs were sold to the negroes with which to mark off their forty acres. A pretended deed for land, sold to ignorant negroes, commenced as follows :—

"Know all men by these presents, that a nought is a nought and a figure is a figure, all for the white man and none for the nigger. And whereas Moses lifted up the serpent in the wilderness, so also have I lifted this damed old nigger out of four dollars and six bits. Amen! Selah!"

In spite of desperate efforts to make the negro a permanent part of the political life of the country, the results attained by negro

politicians never amounted to much. While they got hold of several State Governments, they had little or no effect on the National Government.

The first members were in the 42nd Congress, which convened in the year 1872, and the last went out in the 56th Congress, in the year 1900. It is highly improbable that there will be any more negroes in the House of Representatives or the Senate. The general consensus of opinion of the statesman of the United States is that the negro, after centuries of contact with the white race, is unfit for self-government.

The period of Reconstruction is known as the dark days in the South. The whites saw with terror the dangers of a black peril; in every State political corruption was rampant.

What was to be done? To use force was out of the question. Had the South tried to resist by force of arms, the whole strength of the victorious Union would have been arrayed against her.

One peculiarity of the ex-slaves was taken advantage of by their former masters, namely, the negro's intense superstition and fear of the supernatural. It was this fear that made possible the work accomplished by such organizations as the Ku-Klux Klan.

These societies were secret companies which sprang up all over the South. The members wore a disguise of a white mask, a tall cardboard hat, a gown or robe that covered the whole person, and when a member rode on horseback, a white cover for the bodies of the horses, and a sort of muffling for their feet.

Wherever ex-slaves grew unruly, disguised horsemen appeared by night, and thereafter the negroes of the neighbourhood remained under cover after daylight failed. The black voters were informed by the "spirit horsemen" that negroes should keep away from the ballot-boxes. And on the whole negroes followed the supernatural advice.

Granting the franchise to the ex-slaves proved a grievous error. Most of the political history of the South since the War is bound up in the question of negro suffrage. It has been almost impossible for a white man to vote as he chose. Perhaps on national questions he was in entire sympathy with the Republican party, yet he dare not throw in his lot with that party in the past, as it stood for negro domination in the South.

Enfranchising the ex-slaves brought about a vast solidarity in the social and political life of the South, so that one heard of the "Solid South" in politics. The class distinctions between the whites of the South were by no means so sharply drawn as they would be had there been no negroes.

The wisest men in the South saw the dangers of the secret societies in maintaining the supremacy of the white race. They realised that a disregard for the statutes of the land would lead to lawlessness. So the methods of the Ku-Klux Klan and kindred organisations were dropped, and a constitutional solution of the difficulty was sought.

After the Civil War two amendments to the Constitution of the United States were adopted, namely, the 13th and 15th. The 15th amendment reads as follows :—" The right of citizens of the United States to vote shall not be denied or abridged by the United States or by any State on account of race, colour, or previous condition of servitude. The Congress shall have power to enforce this article by appropriate legislation."

In all the Southern States the negroes were illiterate, and by degrees laws were passed calling for an educational qualification before the franchise was granted. This law has debarred the vast majority of the ignorant, penniless negroes from the ballot-box. Practically all the Southern States have passed laws qualifying the franchise. Here is an epitome of the legislation :—In all of the Southern States any negro who possesses a limited amount of taxable property, valued at $300 (£60 about), and can read and write the English language, is allowed to vote; in three of the Southern States any negro who can read and write the English language, and has paid his poll-tax can vote, although he own no taxable property; and in three States he can vote if he owns taxable property, even though he cannot read or write. In none of the Southern States is a negro legally disqualified from voting because he is a negro; in none of the Southern States is he disqualified if he possesses $300 worth of property and gives evidence of his ability to use intelligently the English language. It was simple enough for the Southern States to adopt these laws, but they had to pass before the searchlight of the highest tribunal in the land, to decide whether they infringed the constitution of the United States. When the Supreme Court of the United States decided that these laws of the Southern States did not conflict with the Constitution of the United States, there was a feeling of relief in the political life of the South.

The contention of the South all along has been that each State has the right to decide who shall vote, and who shall not vote. It is not a question for the National Government to decide.

What an extraordinary page of history is this experience of negro suffrage in the South! The conquerors declared that the freed slaves should become full-fledged citizens at once. The former masters quietly made up their minds to die rather than lose their ascendency. Their ingenuity saved a situation which could never have been won by force. It was one of the critical situations of modern times. Had the Southern people been of a less heroic mould, the future race might have been negroid, for you cannot acknowledge the absolute political equality of a race for ever, without acknowledging the social equality as well. Instead of the future of the South being worthy of the records and ideals of the Anglo-Saxon race, it would probably have sunk to the low level of a South American Republic. Now in the South laws of restriction have been passed to keep out the vast bulk of illiterate, indigent negroes, to take from them what they never had a right to, the vote given by a power which had no right to give it.

There is a terrible side to the negro question in America, namely, the unmentionable crime against white women. While the women of the black race can walk unmolested (so far as the white man is concerned) from one end of the South to the other, the wives and daughters of the white men in lonely districts dare not go far into the forest or away from their male protectors, lest a fate worse than death overtake them.

The chief explanation of this "New Negro Crime" can be traced to the promiscuous granting of the franchise. It was preached to the negro that he was the equal of the white man in every way, that he was free to do as he pleased.

The "New Negro Crime" will disappear when the conditions which brought it about pass away. Take the case of Mississippi, where the blacks greatly outnumber the whites. Since the disfranchisement of the negroes the crime has practically vanished from this State, where the negro has learned that, whatever may have been the theory that inspired reconstruction legislation, the black man in that State is not the political, much less the social, equal of the white. The crime is liable to vanish from the other States when the same hard, but indispensable, lesson is driven home.

The social and economic side of the negro question presents as great a problem as the political. To-day the two races are further apart in social relations than ever before, and the breach is ever widening. The difficulty of the negro problem is enhanced by the fact that the vast majority of the blacks are concentrated in the Southern States. The figures are, roughly, 8,000,000 in the South, and 1,000,000 in the North.

The negroes are not increasing at a greater rate than the white race. Numerical supremacy of the blacks in the South is a danger that will not threaten the country. During the years 1880-1890 the increase of the coloured population in the Southern States was only 13.24 per cent., while that of the whites for the same section was 23.91 per cent. The increase of white population for all the United States was 26.68 per cent., while the increase for the whole coloured population was 13.51 per cent. It might be claimed that the large immigration of the past 50 years is responsible for the big increase of the white population, but the South has scarcely felt the tide of immigration, which flowed to the West and North.

The tendency of the negroes of the United States, both in the South and North, to flock to the cities is very marked. In 1860 fourteen cities in the Southern States contained a black population of 18.85 per cent., while in 1890 these large cities had 29.08 per cent. coloured population, although the total per cent. of negro population for the whole country was less. There are few such instances of wholesale migration to the cities as is shewn by the negroes.

In the cities the negroes concentrate in single wards. Needless to say, these districts are the most undesirable parts of the cities. The vast majority of the criminals come from the negro wards. Extra police precautions are taken.

There is no reason for this flocking to the cities on the part of the negroes. In two of the richest agricultural States of the Union, Ohio and Missouri, the negroes are leaving the land for the cities, in spite of the demand for their labour as farm hands. Once in the city, the negro seldom goes back to the country.

The negroes in the country generally congregate in certain counties, known as the Black Belt, principally in the neighbourhood of the Mississippi River. In these districts the negroes greatly outnumber the whites. Here are some of the most striking instances of the disproportion of the two races in a few counties of the black belt. In East Carroll parish, Louisiana, there are 11,394 negroes to 1000 whites; in Madison parish 14,183 negroes to 1000 whites. In the county of Beaufort, South Carolina, there are 11,659 blacks to 1000 whites.

Let us now consider the vital statistics. Of all races for which statistics are obtainable, and which enter at all into the consideration of economic problems as factors, the negro shows poorly in his power of resistance in the struggle for life. In the South the negro birth-rate is in excess of that of the native whites. In the Northern States the negro mortality is in excess of the natality. The death-rate of the negroes is far and away higher than that of the whites all over the States. *In the cold climate the negro race would die out in a few generations were it not for the continual influx from the Southern States.*

Here are the relative death-rates of the two races in six Southern cities, taken from the 12th Census of the United States. The death-rate is per 1000 population :—

New Orleans, Louisiana	White	death-rate	20.666	per	1000
	Coloured	,,	39.740	,,	,,
Louisville, Kentucky	White	,,	13.914	,,	,,
	Coloured	,,	24.935	,,	,,
Richmond, Virginia	White	,,	18.088	,,	,,
	Coloured	,,	32.835	,,	,,
Nashville, Tennessee	White	,,	18.269	,,	,,
	Coloured	,,	30.66	,,	,,
Charleston, S. Carolina	White	,,	21.371	,,	,,
	Coloured	,,	43.080	,,	,,

It is sometimes stated that environment explains the very high negro death-rate. While environment plays an important part, there is no doubt that the factors of race and heredity are the chief causes for this high death-rate. Given the same conditions, whether the most favourable or unfavourable, you always find the higher death-rate amongst the negroes. Even in the swamp lands, where malarial and typhoid fevers are prevalent, the white men stand the unhealthy conditions far better than the black men. The African race in America seems to have deteriorated during the past hundred years, especially in the last thirty years, for there is a much higher death-rate now than formerly.

Of individual diseases, by far the greatest number of deaths is due to consumption. This dread malady is decidedly on the increase amongst the negroes of America, while amongst the whites it is steadily decreasing. Even under ideal hygienic conditions the negro shows an increasing tendency toward consumption. Let me give some figures for three American cities bearing on this point, taken from the census of 1890 :—

Mortality from Consumption (per 100,000).

New Orleans, La	335 whites	686 blacks.
Washington, D.C.	245 ,,	592 ,,
St. Louis, Missouri	160 ,,	606 ,,

The figures from St. Louis are very remarkable. They show how well the white inhabitants stand the cold winters of this severe climate, so far as consumption is concerned, and how disastrous the effect is on the black race.

The religious life of the negro in America is an interesting aspect of the subject. His religion is greatly coloured by his African origin. As a rule, religion and morality are two distinct things with the black people. When I was a boy, I remember well how the white folk would guard their hen roosts and water melon patches, whenever there was a big negro revival on. It was not uncommon to hear of a convert to the Coloured Baptist Church stealing a new suit to be baptised in.

But the negro is very religious even when immoral. It is generally of an emotional nature, and only those denominations, like the Baptist and Methodist, where shouting, mourning, and ducking, and all other such ceremonies are in use, can boast a large membership amongst the negroes. Such denominations as the Presbyterian have an insignificant following. At their meetings the observer notes the hypnotic influence of the preacher and shouters on the congregation. Long before the service is finished, a number of the negroes are completely hypnotized. They readily respond to the suggestion of the speaker, and see all kinds of visions, which they sometimes describe at the top of their voices.

There is little of the moral imperative in the negro's religion. In fact, one of the saddest aspects of the subject is the immorality, and especially the unchastity, of the race. Education of the negro has not improved his moral tone. Recent reports of the United States census returns show that in the case of the district around Litwalton, Virginia, the younger generation of negroes possessed more property and "book learning" than their fathers. But in respect for the rights of others, in manners, and in character, the younger generation are distinctly degenerates. In many cases education has elevated the individual, but the moral tone of the negro race to-day is lower than it was before emancipation. Take the returns from the city of Washington, where the negro has greater opportunities for advancement, and less excuse for the infringement of the moral law than anywhere else in the world. What do we find? In 1870

the percentage of illegitimacy of the total number of coloured births was 17.6 per cent., and for the whites 2.32 per cent. In 1894, 26.46 per cent. for the blacks, and for the whites 2.56 per cent.

The negro women are the most discouraging part of the whole negro problem. There are some who possess intelligence, nobility of character, but they are the exceptions. The change which came with the Civil War has been for the worse, and there are undoubtedly signs of decadence of the women of the negro race.

Let us turn to economic conditions and tendencies. The negro's greatest sphere of usefulness is as an agricultural labourer. But he rushes off to the overcrowded cities, and tries to get into the overcrowded professions. The negro farm labourer, when good, is very good. He is especially fit to labour in the cotton and corn fields, for he can stand the fierce heat of the sun. His weak points are lack of perseverance and unreliability. Many a Southern farmer has lost heavily through the desertion of his negro labourers at a critical moment.

Even when he owns his land, as many do now, the negro cannot be compared with the peasant owners of other countries, as France, for instance. The negro's wants are limited. He has little ambition. He cultivates just so much, and no more. If he has a farm of 20 acres, and he can eke out a livelihood from three acres, he allows seventeen acres to remain fallow. Little benefit accrues to the community from negro ownership of land.

The fact seems to be that the South will lag behind the world industrially in just so far as she depends entirely on negro labour. Sad to relate, the huge sum of $800,000,000 spent on the education of the negro since the Civil War, has done little to fit him for his spheres of servant and peasant. In the South there are technical schools exclusively for negroes. They are not servant-training schools. The negroes there are taught to be masters. The majority go out into the world determined to break loose from the white man.

On many of the plantations of Louisiana white labourers from Southern Europe are employed instead of negroes. Perhaps this is the beginning of a gradual replacement. What earthly chance will the negro have if he lets the labour for which he is suited slip from his hands? The educationalists teach him that, given the same knowledge and training, he can compete with the white man in any walk of life. This is a false, a pernicious doctrine, and it is absolutely unjust to teach it to the black man: The greater part of the education of the negro in America to-day is, in my opinion, doing far more harm than good. There will be a whirlwind some day!

Since the war the presence of the negro has been a clog, in one sense, to the industrial advancement of the South. Labour has been more or less despised by the white man. Every inducement has been offered the negro to carry on the rough work of the country. Partially he has refused. The white man has been forced to take

off his coat and go to work. He is beginning to learn the important lesson that has made his brother of the North such a marvellous success—the dignity of labour. Owing to the presence of the negro it has taken the white man at the South nearly one hundred years to learn how to work.

In the development of one great industry of the South the negro has taken no part. In the cotton mills no negroes are employed in any of the skilled work. The negro cannot be relied on year in and year out to work in these mills, and as reliability is a necessity, skilled white labour is employed.

Many of the Miners' Unions admit negroes on full terms, but the blacks prefer not to become miners. The fact of the matter is that the negro dreads continuous and confining toil, and prefers living near the poverty line, rather than mounting to a higher position by hard work.

The question of race amalgamation is one that has often been discussed in America. By the people of the South, race amalgamation is viewed with horror, and if there is one thing on earth they are determined on, it is that this amalgamation shall never come about. Ask the leading negro men their views on the subject, and you will find that those who are candid enough to tell you, have a passionate faith in amalgamation.

Substantially all of the States have laws against the intermarriage of blacks and whites, and the exceptions are in those States where either no negroes live or where they are so few as not to be regarded by the law-makers. Even intensely pro-negro legislation, supported by military power in the Southern States during the reconstruction period, did not dare to legalize intermarriages of the blacks with the whites. The words of Abraham Lincoln are very true:—"There is a physical difference between the white and black races, which I believe will forever forbid them living together on terms of social and political equality."

This brief account of the negro in America makes a rather dismal story. We all know the phrase "the white man's burden," but I believe the people of the South have had, and still have, the greatest part of the burden. The negro question is one that weighs heavily on the keenest brains and the kindest hearts of the South. To-day it is recognized that their first duty is toward their own race, who, in some sections, are vastly outnumbered by the negroes, the thousands of poor whites who never received a cent in money, or any sympathy from the flood which burst over the South from the North after the Civil War. These unfortunate whites are well worth training, well worth helping.

For the sake of the negro himself, the poor whites, or "white trash," as the negroes derisively call them, should be educated and elevated. It is found that most bitterness, most race hatred exists in those districts in which the white race is most illiterate. In communities where the white race is highly educated, the black race is treated with a helpful kindness that astonishes the visitor.

Facing back over the history of the negro in America is not cheering. Looking forward is trying to the stoutest-hearted optimism. Africa still mocks America from her jungles. In the words of William Garratt Brown, " Still," she jeers, " with the dense darkness of my ignorance I confound your enlightenment. Still with my sloth I weigh down the arms of your industry. Still, with my supineness I hang upon the wings of your aspiration. And in the very heart of your imperial young Republic I have planted, sure and deep, the misery of this ancient curse I bear."

We have come to the end of the subject.* Perhaps a few remarks on the Native problem in South Africa will make a fit ending to this paper. I believe South Africa can learn a great deal from the bitter experience America, especially the Southern States, has had in the past.

The first lesson to learn is the danger of too hasty legislation. How much better it would have been after the Civil War had the wild Radicals been kept under, and far-seeing statesmen been at the helm of State. No such hasty legislation would have been passed, and the condition of the negro would have been better to-day. In such momentous questions the greatest care and the greatest study are essential.

The next lesson to learn from the American experience is this :— Beware of the enthusiastic, irrational sentimentalist. He sets out in the world with his sails all a-flying, expecting to do good at every turn, but he generally succeeds in inflicting irreparable damage. Some one has said that the irrational sentimentalist does as much harm in the world as the rational blackguard. Most of the Radicals were sentimentalists, ignorant as babes of the issues involved; some of them were unscrupulous, scheming politicians, who cared not what became of either race in the South, so long as their ends were accomplished.

The next lesson is the education of the negro. I have said that education has done little for the negroes as a race. The wrong kind of education has been given the negro, exactly the same as a white child receives.

No doubt the reason for this is the wave of liberalism which swept over the world, so that men looked at things as they desired them to be, not as they actually were. The declaration " All men are created equal " becomes on scientific enquiry an absurdity. All men of the same race even are not equal. Most of us would like to equal Shakspeare in poetry, or Newton in Natural Science, but we know how woefully unequal we are to these great men.

What is true of men is also true of races. The fatal mistake made in America in dealing with the negro race was that it was supposed that the black man was the white man's equal in every respect, and only required the same environment and the same opportunity to equal the achievements of the Caucasian race. The fact is that race traits and tendencies have been neglected too much in the study of nations, and that environment has received more than its due. There is abundant evidence that we find in race and

heredity the determining factors in the upward or downward course of mankind.

One of the most important lessons of all can be learned from the history of lynching in the Southern States. The most awful side of lynching is not that some miserable creature is put out of the world, but the effect of the practice on the mobs. They learn such lessons of lawlessness that all respect for law is liable to disappear. One of the reasons for lynching has been " the law's delay." Instead of the negro ruffian being tried and executed expeditiously, there are delays and formalities, and in many cases a sentence in no wise commensurate with the crime. No one wishes to see the practice of lynching introduced into South Africa. One of the surest ways to prevent it is to have such a stringent law against the offence for which negroes in the South are lynched, that even an attempt of the crime meets immediate death at the hands of the law. If such laws are passed and carried out, the people will realize that their women folk are safe, and will not resort to lynching. On the other hand, if the crime is dealt with lightly, as it has been on several occasions in this country, as sure as to-morrow's sun rises the people of this country will some day resort to the same awful method that prevails in many districts of the South to-day.

Every woman in South Africa should learn the use of fire-arms, especially of revolvers. Not only have many women in the South owed their safety to skill in the use of a revolver, but in the West as well women have often protected themselves from the Indians by being crack shots.

Another important lesson for South Africa is the necessity of solidarity in dealing with the negro question. You have heard of the " Solid South " in connection with politics. The explanation of this phalanx, which remained unbroken so long, was the practical unanimity of opinion on this vital question amongst the white men in the Southern States. It will be fatal for Cape Colony to have one native policy, and the Transvaal to have one diametrically opposite. There should be, there must be, a uniform native policy for the whole of South Africa. The negro question in the Southern States has been instrumental in knitting the white people close together. In South Africa perhaps a common problem will do much to bring together the divergent members of the white race.

There are unmistakable signs that the North has far different views on the negro question than formerly. It is felt now that the problem of the negro is a national problem. And so in South Africa, the negro question is one that vitally concerns the whole country.

I have stated that millions of dollars were lavished on the negroes by the philanthropists from the North. Little of their wealth was expended in helping the poor of their own race. The " white trash " had to stagger along without much outside help. In this country force of circumstances will produce a large " poor white " class. Let your hand and your heart first go out to the distressed of your own race before giving money and energy to the education of the native.

And in the education of the negro much can be learned from the bitter experience of the South. Most absurd notions were held on the subject of educating the black man. In far too many cases Greek, Latin, and Hebrew were taught the unfortunate pupils. The consequence is that on the whole education of the negro in the South has proved a dismal failure.

That an increasing number of natives of South Africa will be educated I have no doubt. It is fair not only to the white man but to the negro as well, that the proper kind of education be given him. It is a gross injustice, for instance, to train the native to be a skilled artisan, and then drive him from end to end of South Africa in a vain search for work; to make a lawyer out of him and prevent him from practising. Instruction should be given him through the medium of his own language, and not by means of the classics of Greece, Rome, or England.

There is one thing that the negro in America, in the majority of cases, is sure of getting, and that is justice before the law. There are cases, no doubt, of gross injustice, but the courts as a rule see that the negro gets equitable treatment.. In South Africa it should be the same. Nothing is appreciated more by the negro mind than plain justice.

I have spoken of the horror with which the Southern whites view the subject of amalgamation with the negro race. It is their *bête noir*. A negro leader in America said recently that the "Anglo-Saxon is the most arrogant and rapacious, the most exclusive and intolerant race in history." Quite so, and when it loses these qualities it will cease to exist. Race purity is becoming a passion in the South. In no part of the limitless lands of the Anglo-Saxon are the ideals of our race cherished more than in the South. I hope the same passion will grow in this country, and that any approach to amalgamation will be viewed with dismay.

The last lesson is the most important of all. As I have already intimated, the wholesale enfranchisement of the freedmen has proved one of the most colossal blunders of political history. It has been a real cause of the decline of the negro race in the South. That for which the white man struggled for years was freely given to the blacks. What marvel then that it stultified their development and checked real progress and effort. Politically, the negro was made the white man's equal. In consequence he concluded there was no difference whatsoever between himself and his former master. The race has never climbed the steep and rugged heights along which every people that has become great must toil, but has been lifted on a flowery bed of ease to the summit. Let not the same political blunder be made in South Africa!

In conclusion, I beg to state my indebtedness to Hoffman's "Race Traits and Tendencies of the American Negro" (The Macmillan Co., New York) in the preparation of this paper. This work should be in the library of every one in South Africa interested in the Negro Problem.

20.—THE THEORY OF WITCHCRAFT AMONGST SOUTH AFRICAN NATIVES.

BY REV. H. A. JUNOD.

It is somewhat assuming to search for reasonable principles in the monstrous superstition of Bantu witchcraft. Can there be a theory in absurdity? However, under every belief of any human group there is a philosophical conception of some kind which explains why that belief has taken such a hold on the minds of the community, and however ridiculous that conception may be, it is the duty of the Ethnologist to try to discover it. That is the only way to understand the mentality of the savage.

Witchcraft is flourishing amongst South African heathendom more brilliantly that anywhere else on earth! In fact, it seems that, not satisfied by the scanty religious ideas that he possesses, the native mind has taken a special pleasure in developing beyond all limits the wonderful fancies of witchcraft. White people have very little idea of the richness of imagination of the natives in that domain. But white people, as a rule, even those acquainted with the native language, do not understand properly what is witchcraft, for the natives. There are two sets of conceptions which we include under that name, which exist also in the mind of the Bantu, but which are entirely separated for them. The other day a cablegram, entitled "Witchery Exposed," which I read in the *Transvaal Leader*, announced to the world that Bambata was very much deceived by the death of his warriors shot by the Natal Troops, as he thought that, by *means of witchcraft*, the bullets of the white men would be turned into water. Now, that kind of magical operations which some special men pretend to accomplish is very different from what we generally mean by witchcraft among natives. Those magical operations are called *bunganga* or *bungoma* in Thonga; *bugoma* in Suto, *bungone* in Zulu, and the kind of prophets, thaumaturgers, divinators, doctors, who perform them, the *tinganga* or *bangoma* (sing. mungoma), are held in high esteem. The witchcraft proper, that is, the power of the evil eye, is an entirely different thing. It is called *boloyi* in Thonga and Suto; the people who perform it are very much dreaded, and looked upon as great sinners. They are called *baloyi* (Thonga: noi, sing. baloyi, plur. Suto: muloi, sing. baloyi, plur. Zulu: mthakati, sing. abathakati, plur.). Their horrible actions are called: *ku lova* (Ronga, Suto) or *ku lowa* (Gwamba) or *ukuthakata* (Zulu). These two kinds of operations, though both miraculous, are so widely different in the eye of the native, that the one, the power of the divinator, is resorted to in order to check the power of the other, the witch.

I do not intend to speak of ordinary magic to-day; but I should like to sketch the wonderful superstitions of *buloyi*, with the view of finding out where they come from, and how they are related to the animistic system of the Bantus. My remarks apply more especially to the Thonga tribe, which is one of the strongest of South Africa, extending from Zululand to the Sabi River, and

occupying the N.E. corner of the Transvaal and the Delagoa Bay district. I studied it amongst the Ba-Ronga of Lourenço Marques and the Ba-Nkuna of the Selati district. Here I am staying amongst the Pedi-Suto, of the Ba-Kaha clan, and have opportunity of investigating the Suto ideas. My impression is that the South African tribes as a whole do not differ substantially as regards their conception of *buloyi*.

1.—THE BALOYI.

The *baloyi*, or people who have this evil eye, are numerous in each tribe. This power is hereditary, but, strange to say, it is transmitted by the mother and not by the father. Therefore should a polygamist have 3 wives, one of whom is a *noi*, all the children he will have from that "noi"-wife will be *baloyi*, and his other children will not be such. That dreadful power is sucked from their mother's breast when they are still infants, but it must be strengthened by special medicines to be really efficient. The "noi" mother chooses one of her sons, to whom she does not dispense these drugs, and he will be free from *buloyi*. Her aim in doing so is that, should one of her offspring later on be accused of having killed by witchcraft and be called to pass through the ordeal (of which we shall speak hereafter), the immune child will be sent in his place to undergo the trial. The chief will consent to that substitution, as it is well known that all the sons of a "noi" woman are equally *baloyi*. But the intoxicating medicine of the ordeal will have no effect on the substitute, and therefore the true *noi* will escape!

Those *baloyi* know each other. They form a kind of secret society amongst the tribe, and they assemble—with their spiritual bodies—during the night to eat human flesh in the desert. There they form a true "hubo," that is, a debating assembly. They discuss what they will do to injure property or destroy life. They fight sometimes. If one of them is defeated in the discussion (saying, for instance, that there should be no mealies this year, a proposal which is not accepted by the others) they condemn him to pay a fine, and the fine will consist in a human body, which he will have to provide, after having killed it by witchcraft. It might be that he will choose his own child to bring it to the horrible banquet. It shows that there are powerful and less powerful *baloyi*, and they are constantly trying to overcome each other in finding out more efficient charms.

As regards the other members of the tribe who are not witches, or wizards, they are considered by them as stupid beings who do not deserve a better fate than that of being eaten wholesale by the clever *baloyi!* These men-eaters are the truly intelligent, the superior, the wise ones! But the others fear them immensely, and when a boy wants to marry, the main thing to consider in the choice of his wife is that she does not belong to a family of witches. Therefore the accusation, "You are a *noi*," is the gravest insult which a man can make to another.

The activity of the *baloyi* is almost entirely nocturnal. In fact, they possess the faculty of getting out of themselves, during the night; they fly, have large wings, and, after having got out of the hut by the crown of grass which covers its top, or by the closed door, they fly through the air and go to their horrible work. The little flying flames which are seen sometimes in the marshes, the will-o'-the-wisp, are considered as being one of the forms under which they go. *

Two questions arise here. Does the native mind think that a true unsheathing (dédoublement) of their personality takes place then, or that they get out of the hut themselves, as entire beings, with their ordinary "ego"? As far as I could make out, the Suto theory is different from the Thonga view. The Ba-Suto say: The witch is going entire, soul and body. Nothing remains on the mat, when he has departed for his nocturnal ride! He throws charms on the other inhabitants of the hut, and they sleep so heavily that they do not notice anything. The Ba-Thonga speak differently. According to them, the *noi* is but a part of the personality. When he flies away, his "nthuti," his shadow, remains behind him lying down on the mat. But what is this shadow? If we could make it out, we would learn something worth knowing about native psychological conceptions. It is not truly the body which remains. It appears as such only to the stupid non-initiated. In reality what remains is a wild beast, the one with which the *noi* has chosen to identify himself. The fact has been disclosed to me by the following striking confession made to me by a very intelligent Nkuna. "Suppose," he said, "my father is a *noi* and I am not. I want to marry a certain girl because I love her. My father knows that she is a *noi* because they know each other, and he tells me: 'Don't do that! She is clever; you will repent!' However, I persist in my idea. He urges me to leave that plan, and threatens me with great misfortune. I marry her. One night, my father enters my hut and awakens me. He says to me: 'What did I tell you! Look! Your wife has gone!' I look at her place and find her sleeping calmly. 'No. Here she is.' 'It is not her! She is away! Take this assegai and stab her.' 'No, father, I dare not.' 'Do, I say!' And he puts the assegai in my hand and makes me violently hurt her leg. A cry, the cry of a wild beast, is heard. And a hyena appears instead of my wife, a hyena which deposits its 'faeces,' because it is frightened, and which escapes from the hut in howling. My father gives me some powder to swallow and I shall be able to see the *baloyi* and their ways and habits. He leaves me—very much trembling from fear—and goes home. When the sun is going to appear, I hear a noise like that of the wind in the branches, and suddenly something falls down from

* Amongst Christian natives you will find some who believe that the will-o'-the-wisps are the spirits of the deceased which come back on the earth. But I strongly suspect this idea of being of European origin. For the Bantu, the ghosts of their ancestors, which are their gods, appear sometimes, but under the form of snakes, around the graves, near the village in which they lived, and the will-o'-the-wisps are the *baloyi*.

the top of the hut near me. It is my wife. She lies down sleeping, but her leg presents a wound, the wound that had been made in the hyena!"

From this dramatic story, it must be inferred that in the idea of the Ba-Thonga there is truly an unsheathing of the personality into two when the *noi* goes to its nightly work.

A second question arises, which is this: As the *baloyi* lead a double existence, a day-light one, where they are but men, and a nightly one where they perform their work as witches, are they aware, during the day, of what they have done during the night? In other words, are they conscious of their doings as witches? The question is difficult to answer, as there does not seem to be a clear idea on this point in the native mind. The old, genuine representation is that a *noi* does not know what he is doing; he is not even aware that he is a *noi* as long as he has not been revealed as such by the means which we shall see later on. Therefore he is unconscious. His nightly activity is unknown to him when he has come back to his daily, ordinary life. For instance, my informants assure me that a man might have sent a crocodile to kill another one, during his *noi*-existence, but he will be the first one to show sympathy to the poor wounded, to be grieved for this sad accident. And he will be amazed, when the diviner points to him as having caused the death by his *buloyi*, of which he was in perfect ignorance. But it seems as if the *baloyi* which have long practised their horrible tricks are aware and even proud of their doings, and therefore more or less conscious of their double life.

But let us hear what are the dreadful acts which they are committing under their *baloyi* form.

2.—THE CRIMES OF THE BALOYI.

(a) The *baloyi*, first of all, are thieves. This is the least criminal aspect of their activity. They steal mostly mealies or the products of the fields. The native doctors have a kind of medicine with which they plaster their mealie cobs in the gardens, and the *noi*, when he wants to tear them from the stalk, remains prisoner on the spot, unable to draw his hand away from the cob! But, what is even more curious, the *baloyi* of a country assemble to make up an army and go to fight with the *baloyi* of another one, in order to deprive them of their mealies and bring them into their own fields. For instance, in 1900, there was a great war between the *baloyi* of Mpfumu, near Lourenço Marques, and those of the peninsula of Inyack, at the entrance of Delagoa Bay. That year the Kafir beans were plentiful at Mpfumu, and it was explained by the fact that the Mpfumu *baloyi* had had the victory over their Inyack enemies. They owed their success to the following trick. They gathered any number of seeds of a little cucumber called *nkakana*, and made with them a kind of enormous ladder, which was suspended midway between sky and sea; over it they crossed the 20 or 30 miles of the bay of Delagoa

and stole all the Kafir beans of Inyack. Should a tempest have uprooted trees and broken branches, people are sure to say : Here the "yimpi of *baloyi*" has passed as a terrific storm during the night.

(b) But the great crime of the *baloyi* is that of killing. They are murderers, and all the more to be feared as they act unconsciously, perhaps, at anyrate, without being seen or known. Two motives inspire their crimes—hatred and jealousy. Should one of them have been offended, he is sure to revenge himself by putting to death his enemy. During the night, he escapes from his hut (as we have seen above), he opens his wings and flies directly to the dwelling of the man he hates. But the habitation of that man is well protected. Just as the village is surrounded with a material fence of thorns, leaving only the main entrance and some smaller ones, there is all round it a spiritual fence made up of charms, various medicines, which close the kraal against any invasion of witches. Across the main entrance even there is a stick daubed with certain magical powders which prevent him from penetrating inside. How must he act, however, to perpetrate his crime? He has first made an agreement with another *noi* residing in that village, and who has wrought an opening in that spiritual fence, similar to one of the small holes of the material one! He then gets into the kraal, descends through the grass roof into the hut of the enemy sleeping calmly on his mat. Then he proceeds to the bewitching operation. It can be performed in various ways. The main ones are as follows : Either he lies over the man as a vampire and sucks all his blood, or he takes him and goes away with him to the big *baloyi* gathering, where the victim will be eaten just as a goat when they make a feast : the limbs will be distributed to all the assembly. The one will eat the leg, the other the head. The *noi* has perhaps a fine to pay to his companions, and he will bring it to them. Whatever may be his way of proceeding, the result will be the same. The poor bewitched man is condemned to die! "O loyiwile," he has been bewitched; "ku sa nthuti ntsena," his shadow only remains. They say also the "nthumbu," the corpse only has been left, his true self has been stolen and eaten. He will get up in the morning, die some days later, but what will die is only his shadow. Himself has been killed during that frightful night. He has been eaten already! Here we find again under an even more mysterious form, the idea of the duality of human personality. How it is possible that a man who has still to live some days or months may be considered as already eaten up entirely, I do not pretend to explain. Such is the native idea, at any rate. A Mosuto tried to overcome the difficulty by saying that what the *noi* is taking with him to eat is the inside, the bowels; the external frame only remains, and the man will die soon! Most of the natives, when you show them the absurdity of the idea, laugh and that is all.

The *noi* has still at his disposal at least five means of bewitching called *ruma*, *mitisa*, *matshelwa*, *ntchutchu*, and *mpfulo*.

The *ruma* (to send) consists in sending either a crocodile, or a lion, or more often a snake, to the place where the enemy is going

to pass. He will be killed or wounded. Or, if the *noi* does not wish to do so much harm, he will only send antelopes to destroy the fields and eat the sweet potatoes. Even in our Christian village, during the days when the "duikers" are plentiful, and become a nuisance owing to the fact that the natives have no more guns, you might hear somebody saying: *They* are sending us their duikers! Who are *they?* Mystery! *They* are the *baloyi!* But do not call them by their name!

The *mitisa* (ku *mita*, to swallow, ku *mitisa*, to make somebody swallow) is the only means of bewitching which is used during the day. It consists in giving to a visitor something to eat or to drink in which certain drugs have been introduced. The mealié pap or the beer seem perfectly normal, but owing to the enchantments of *buloyi*, as soon as you have swallowed them, they are transformed, in your throat, into any kind of harmful beast, which threatens to suffocate you, and gives rise to a disease and perhaps produces death! You will have swallowed in this way a snake, a beetle, of the copris genus, one of those strange dung-eaters, a big fly, or certain kinds of meats of animals. The great effort of the native doctors to whom you will apply for treatment will be to remove these foreign bodies, and when you vomit they will show you with triumph a bit of bone, a tooth, that famous beetle, or other objects which they had previously and cleverly introduced themselves. . . . There is a medicine which natives like to have inoculated into their tongue, and which has the wonderful property of forcing the bewitched food to reveal its true character when you eat it. If you have been treated with it, you will hear the cracking of the elytra of the beetle, and at once be able to spit out of your mouth the death-containing food!

The *matshelwa* (ku tshela, to throw) are precisely these foreign bodies which the *noi* introduces into you by the way of giving you poisoned food, but during the night, when he lies down over you and wants to kill you in a slower, more mysterious way than by sucking your blood or stealing your spiritual body!

The *ntchutchu* (ku tchutcha, to inspire) is another way of getting rid of an enemy. It is a bewitching of the will by which the *noi* inspires his enemy with the idea of leaving the country. Without motive, the poor bewitched prepares himself to go to Johannesburg or anywhere else. There he will become the prey of other *baloyi*, who will kill him. When a boy dies in the mines, as hundreds of them do, his parents think: He has been killed by such and such a disease. But the author of his death is not in Johannesburg, he is here at home; it is the *noi* who hated him and made him go by "ntchutchu."

The *mpfulo* is still worse. That word which comes from the verb ku pfula, to open, designates the mysterious power which the *baloyi* possess to open any kind of things. One of them, a Nkuna, named Nwayekeyeke, had charms to open the kraals of oxen; during the night, he would come into a village holding a tail of hyena daubed over with peculiar medicines, and would throw on all the inhabitants a deep sleep. Then, waving the tail, he would open the kraal and

call the cattle out. Flying with the rapidity of the wind, he would then be followed by all the herd bewitched by him. When tired he would jump on a tree and rest a while, fearing lest the oxen might come over him and tread him down, as they were invincibly attracted by the tail. Should people see him on his way, he would say: "Take an ox, I give it to you," till he reached his village and introduced in his own kraal the stolen oxen. There are other kinds of *mpfulo:* the power of *opening the hut,* of putting away the husband sleeping there without waking him, and of committing adultery with his wife. . . . But the great *mpfulo* consists in *opening a man.* The following story will show how that criminal act is accomplished. Some fifty years ago, a young man called Nkokana, the uncle of my informant, astonished the whole tribe by his splendid way of dancing like the chameleon. The circumcision school was just over, and the last day of it all the boys had to enter solemnly into the kraal of the chief, the back bent towards the earth, the body daubed with ochre, and in moving slowly legs and arms like the chameleon. This ceremony is well known under the name of *tchekatcheka* or *nenga.* One of the men of the tribe who was a *noi* was struck by the perfect performance of Nkokana, and, filled with jealousy, he resolved to bewitch him. As the boys were going home that same day, happy to be at the end of all their trials, they had to cross a thick wood; suddenly a voice was heard calling: Nkokana! The boy said: Yes, I am coming, and he went to the place from where the voice had come. But he found nobody. Instead of going back to his companions who were waiting for him, he ran all through the bush, as possessed by a kind of madness, always following the voice, but with no success. The night elasped. . . He came back home entirely worn out, a shadow only of himself, and died some days later. He had been "opened up" by the witch. When such bewitching takes place, it is probable that the *noi* wants to enslave his victim, and make him work for him. The shadow only dies, but the true self is living and toiling for his persecutor, ploughing his fields, cutting his wood, and so on.

Such are the crimes of the *baloyi* and the seven principal means of bewitching which they possess. They know a number of other tricks. The rich imagination of the natives has full play to invent any number of clever deeds which they attribute to them. What we have said is enough to illustrate the theory of witchcraft.

Let us consider briefly how the common people try to protect themselves against such a terrible danger which threatens them all.

3.—THE PROTECTION AGAINST BALOYI, AND THE WAY IN WHICH THEY ARE PUNISHED.

As we saw, every village is surrounded by a fence made up of charms, which competent doctors put all round to prevent the *baloyi* from entering. A great magician of the Nkuna tribe, Mankhelu, son of the chief Shiluvane, gave me the receipt of the medicine which he

employs for the purpose. It is a kind of ointment in which are contained different powders made up of various sea-animals; the jellyfish (which the natives believe to be the result of the spitting of the whale!), the sea-urchin, the sponge, and others. To these sea-animals are added some roots which have been exposed to the light by the rain which has washed out the soil in the kloof. All these drugs which are also employed to obtain rain are mixed with fat and burnt on charcoal, at dawn, on the road to the village to protect the main entrance. Stones are daubed with it and put in all directions to close other openings. Then a second fire is made before the thresh-hold of the hut, and the smoke which comes out from the magical fat will keep the *baloyi* away. "These medicines act wonderfully," says Mankhelu. Should a *noi* succeed in entering the hut, the power of that smoke will be such that he will at once be revealed. Without any clothing, the *noi* will suddenly be seen there as if dreaming, seeing nothing, knowing nothing. If it is a woman, I will call her husband and show him his wife. . . 'What are you doing here?' he will say to her. She will not utter a word. Then I will tell him: 'Look here, my friend. . . . I might be hard on you. But I have pity. Do not allow your wife to do anything of the kind again. Pay me one or two oxen, and I will keep silent.' He will consent. Then I beat the woman with my stick. She awakes, and, quite ashamed of being in another hut without any clothing, she will fly away home!" Such is the testimony of Mankhelu, and he is sure of having succeeded more than once!!

But should all the protective medicines which surround the village, which have been swallowed by the inhabitants or by which they have been inoculated, remain without effect, should a serious disease occur, one of those evils which are generally attributed to the *baloyi*, the first thing to do is to go to the divinator, who will cast the bones and make out if the disease is due to witchcraft or not. This consultation is secret, and only preliminary. There are in the sets of bones employed in the bantu divination, some which represent the *baloyi*, especially the astragalus of the "duiker," that small antelope which rambles about during the night, just at the time when the witches operate. Should that bone fall in a certain way near the bone representing the patient, it shows that his disease is the outcome of *buloyi*. The name of the *noi* will be searched for and perhaps ascertained that first day, but the parents of his victim will never dare to accuse him only on the testimony of the bones.* The next step will be to go to the mungoma, the magician who "smells out" the *baloyi*. A wonderful personage he is! Amongst the Nkuna the great magician is Nwashihandjime, a splendid man, tall, clever, his eyes beaming with a kind of supernatural light, holding an enormous tail of a horse fixed on a handle richly decorated

* The Ba-Suto of the country generally were convinced by the mere consultation of the bones. They learned of the Thonga to go to the mongoma, and they choose a thonga mongoma to help them. However, they used also the *mondjo* ordeal and were going to Palabora to make it.

with beads and copper wire. He has a very great influence, and the man on whom the tail falls is a lost man! Should there be no white rulers in the country he would be hanged. How is the *mungoma* disclosing the *baloyi?* The father of the bewitched, his parents, come to him, pay him £1, and ask him to find out the murderer of his son. He makes them sit down in a half-circle, and, facing them, begins to put to them some questions. They answer always by the word *mamoo*, which means yes, in the language of *bungoma*. But their *mamoo* is cool or warm, doubtful or convinced, and the clever diviner perceives easily every shade of meaning in that perpetual *mamoo*. . . . He is well aware of all the disputes and hatred between the people and, in his investigation, he draws nearer and nearer to the man of whom the parents are thinking. Their *mamoo* becomes bolder. . . The questions are more precise. . . At last, when he feels himself agreeing with the consultant, the *mungoma* pronounces the name and lets fall his tail. He is bathed in perspiration after the great strain, and he remains silent, as if he were invulnerable; he has triumphantly "smelt out" the culprit. . .

Next day, relatives of the patient go to the kraal of the *noi*, waving branches, dance before him, and say: Thus you are killing us! The accused one keeps silent. Then he says: All right. We shall come to-morrow and consult also our *mungoma*. Both parties then go to another divinator. The scene of "smelling out" is again gone through, and very likely the verdict of the second *mungoma* will confirm that of the first one. . . The augurs know that they must not contradict each other if they want to maintain their authority. As soon as the proof and counterproof have been obtained, the case becomes a judicial one. The plaintiff puts the matter before the chief, who will not condemn before the guilt of the pretended *noi* is confirmed by the ordeal, the trial by the famous philter called *mondjo*. The *mondjo* is a plant of the Solaneae family which possesses intoxicating properties. It is administered both to the plaintiff and to the accused by another doctor who knows how to prepare it. The *noi* who has drank from it is exposed to the sun, and after a little time shows symptoms of drunkenness. The whole scene is very characteristic. The explanation given to me by an old native is this. In the *mondjo* there is a little bit of human flesh reduced to powder, or a bit of bone taken from a leper. The *noi* who eats it in drinking the philter happens to do during the day what he is accustomed to do only at night; hence his loss of sense! He has been revealed as *noi*. In fact, the man who administers the philter is clever enough to give a large dose to the accused and a small one to the plaintiff! The first one, being already under the effect of a strong suggestion, is more apt to feel the stupifying effect of the drug, and his drunkenness is easily explained in this natural way. * In former times there was but one punishment for *baloyi*. They were hanged at once. The last one who was killed in that way amongst the Nkuna is Mudebana, hanged in 1892 or 1893 in Thabina by order of Mankhelu,

* See for more details on the ordeal my book: "Les Ba-Ronga," pp. 431-439.

the regent of the young chief Mohlaba. The Boers having heard about it condemned Mankhelu to death. The whole tribe was terribly excited. The sentence was commuted into an imprisonment of one year, and since then the native tribunal does not dare to condemn anybody for the crime of *buloyi*, although they remain convinced as much as ever of the reality of those crimes.

4.—THE EXPLANATION OF THE ORIGIN OF BULOYI, AND THE MEANS OF FIGHTING AGAINST IT.

It may seem inexplicable that millions of human beings who possess a fair amount of reason and of commonsense, entire tribes which are not among the least gifted in mankind can entertain such absurd, dreadful ideas, as those on which rest the bantu *buloyi*. But let us remember that three centuries ago European tribunals were condemning wholesale hundreds of poor people accused of witchcraft. There, however, was a capital difference. The white witches, our ancestors, who were burnt by thousands all over Europe, were supposed to have made a pact with Lucifer, the Prince of Darkness. That sin was considered as essentially diabolical in its origin. The Bantu have no idea of Satan, and that aspect of witchcraft is entirely absent from their mind.

Let us consider the various elements of the *baloyi* theory and seek an explanation for them. Bantu witchcraft is a direct outcome of the dogmatics of the savages, of that conception of the world which is at the basis of all their superstitions and beliefs. Animism is the name of that dim, confused philosophy, and it consists in projecting into nature the state of things which we find in ourselves. Just as every act performed by man is the result of a determination of his will, so everything happening in the world is the result of an intelligent agent. There is very little or no notion of natural laws in the Bantu. For him a spiritual cause alone can explain the facts, especially those which hurt him and destroy his happiness in life. Apply these principles to this great source of sorrow and disappointment, death, and you will hear him say: Death is only natural when caused by old age. But when a man in his prime, or a lad, a baby, a person still useful dies, he or she must have been killed by a special agent. There are but two explanations of the fact: Either he has injured one of his departed ancestors, one of the gods, and is punished for that offence, or he is the victim of a living man who hates him and bewitched him. That is why a chief of great fame in the Nkuna tribe, Shiluvane, had issued this decree: "I do not allow of anybody dying in my country except on account of old age. Let the *baloyi* at once cease their enchantments or I will kill them all."

The philosophical reason of *buloyi* is then obvious, and that accounts for the fact that it is so widely spread and so deeply rooted amongst the Bantu. But the psychological conception of the native fosters also the belief in *buloyi*. We have seen in two instances that the *buloyi* supposes an unsheathing of the human personality. That idea

is very common amongst primitive thinkers, and it has found a wonderful development in the modern system of spiritism. Whatever is true in it, scientifically speaking, is another question. But we ought not to be astonished at the Bantu superstitions when we see so many philosophers of our time speak of astral bodies, subliminal existence, and so on. That idea of a double life has no doubt found some foundation in the fact of dreams. Dreams are a very important thing for the natives. They are fully convinced of their objective value, and no wonder if they explain a nightmare by the action of the *baloyi*; or if their dreams make them think that they lead a second existence during the night.

When did cannibalism disappear from South Africa? The answer to this question is impossible to give in the present state of our knowledge. But it is likely that the South African Bantu, as well as the tribes of the Equator, passed through that stage and were at a time cannibals. When the distasteful custom began to fade away, it must have left in the minds of the new generations a feeling of disgust, if not of horror. We find traces of it in the numerous tales about ogres of the Bantu folklore, and I guess that if the *baloyi* are accused of the crime of cannibalism it is for the same reason.

Finally, if some people dare to attribute to members of their tribe such awful acts as those of killing, and eating human flesh, it is sufficiently explained by the terrible power of hatred which the savages possess. They know that a native who hates would not shrink from anything to satisfy his desire for vengeance.

In conclusion, I would say: The origin of the theory of witchcraft, the power of that absurd superstition on the Bantu mind, is easily explained when we consider that it is but an application of the animistic system to the problem of death, that it is in accordance with the Bantu psychological conceptions of the duality of the human being and of the objective value of dreams, the remembrance of cannibalism, the intensity of hatred amongst savages; all these facts and principles correspond perfectly with the various elements of the superstitions which have been analysed now.

The only way of getting rid of that dreadful theory which can be really called the curse of the natives, is to replace in their minds that primitive and dangerous animism by the spiritual, highly moral, philosophical theism of Christianity. A Bantu when he becomes a Christian has given the deathblow to his old belief of witchcraft. However, that belief is slow to die! It is one of the superstitions of heathenism which sticks with the greatest obstinacy to his mind, and how often do we see the accusation of *baloyi* thrown in the face of a convert by another convert! Every missionary understanding the natives will agree that any apparition of the *baloyi* superstition amongst those new congregations must be at once denounced as a sin of heathenism, and punished as such by those measures of ecclesiastical discipline which these young Churches cannot yet dispense with.

But there is another very efficient way of putting a check to the *buloyi* superstition. *Buloyi* is condemned as a crime, and the *noi*

must be judged and punished by the chief. Now, since the white Government has taken in hand the direction of native affairs all over South Africa, the native chiefs have seen their power very much diminished. They only judge less important offences. In doing so, they are acting in the name and with permission of their white masters. Accusations of *buloyi* are frequently brought before the native tribunal. The Christian chief generally refuses to accept them. But heathen ones do it, and therefore they uphold in their semi-official capacity that wretched and dangerous heathen superstition. Though we quite agree that the State is not called, as such, to interfere with the beliefs of its subjects, we must recognize that here a civilized Government has a duty to prevent any judicial act which supposes the reality of *buloyi*. And I would suggest a few principles and a few rules which the Department of Native Affairs might inculcate on the subject to its subordinates, the native chiefs :—(1) That the crime of *buloyi* be not recognized under the penal law. (2) That the native chiefs be prohibited from trying any *baloyi* case. These would be the two main principles. I might add the following ones :—(3) The plaintiff must be reprimanded as upsetting the peace of the country. (4) The *mungoma* who pretends to have "smelt out" a *noi* must be fined as employing his authority to deceive people and foster hatred amongst them. (5) No evidence based on the use of divination bones must be accepted.

In the course of time, if that policy is followed, and if a true Christianity and education spread amongst natives, the *buloyi* will have ended, and the grandsons of the actual natives will read with amazement what their forefathers could believe !

21—MODJADJE, A NATIVE QUEEN IN NORTHERN TRANSVAAL: AN ETHNOLOGICAL STUDY.

By Rev. Fritz Reuter, Berlin Mission.

The Name.

Modjadje has its derivation from the word ledjadje, i.e., day or sun; plural, madjadje. Mo is the personal prefix, so that the meaning of the name comes near to: The ruler of the day or the sun.

The original home of Modjadje and her tribe is the country beyond the Limpopo river, called by the natives, Bokgalaka. Even now-a-days the old men of the tribe greet each other by Ndau Mokgalaka, i.e., Lion, man of the country Bokgalaka. In their opinion the whole of the human race comes from there. The tradition of the tribe announces that it was removed to its present abode by a migration of the nations, and that the tribe chanced on a people, who were wild and ignorant of fire.

It is rain-production which brought this heathen race to a power and authority so immense. The rain production was accomplished in a most systematic way. The queen distributed the power of producing "the small rains" to her relations, so that they were co-regents and had their earnings, while she reserved the great rain-producing powers for herself. Generally the great rain was prepared out of the skin of a deceased chief, who was skinned after death. Part of his flesh, mixed with drugs and burned together with the brains of an owl on a coal-fire, effected the rain. Likewise, they prepared rain-medicine out of the material mentioned for reserve purposes, and poured it into oxen-horns. They also placed pots, filled with water, on top of the highest mountains, which were only stirred at fixed intervals by minor chiefs. These are said to produce the small morning-rains and the rains in the harv[illegible] app[illegible]. Sprinkling of the rain-medicine was never done in the rainl[illegible]e, but only in the rainy season.

The number of those who sought for rain was always immense. All the major chiefs of the country appeared and paid their tribute to the queen in order to get the necessary rain. Gold and diamonds, cattle, and human beings, were paid for this precious moisture. Once 22 Zulus from Natal were at Modjadje's for six weeks to fetch rain, but no rain appeared; so a rain doctor with a medicine horn accompanied them on their way home, having strong hopes that it might rain on the long trip to Natal. Once it did not rain for a couple of years, and even Modjadje in her head kraal was in bad want of drinking water; but even then most of her people did not despair of her ability. It was said that certain causes had made Modjadje sad, and had influenced her to such a degree that it was impossible for her to produce the rain until they were removed. In 1884 it was stated that the Christians who had been converted out of her tribe were to be blamed for it, and had to be killed first. This was actually done. A force of about 10,000 men suddenly attacked my Christian village on Good Friday, and murdered the Christian chief, with 40 men, women and children. In 1892 it was said that the invasion of the white people into the Low

Country had aggravated rain-production, and again forces were set a-going to burn down their homesteads; a white man was also murdered. Two native wars resulted from this.

Her wholesale fraud gave Modjadje immense power, so that every one of her subjects who fled into another country was surrendered without further ceremony. The hangman's servants dogged his steps and said: "This man has run away with the rain." The people to whom he had fled replied that it was better for one man to die than for the whole of the tribe to suffer. But in most cases these deserters surrendered themselves, and then were put to death with battle-axes in a most wretched way.

About the time I entered the country the Kaffirs had a beer-feast in a kraal not far from my station. There they drank and danced and committed all sorts of abominations until they were exhausted. At that time a fire broke out in a place far away, which, by a strong wind, was driven towards that kraal, and the huts and hedges became a prey of the flames. Most of the people were so drunk that they could not escape, and were burned. I tried to save the chief's wife and her daughter, but the burns were of such a nature that they also died. Now a great trial was started to find out the guilty person, who by witchcraft had directed the fire to this place. By means of dice it was at last discovered that it was an old man of the same kraal, who, of course, was in possession of a good lot of cattle; he had not been one of the drinking party. This man was condemned to death as having called the fire by witchcraft in order to annihilate these people. The poor old fellow fled into the bush and hid himself in the long grass, which was set on fire at once, whilst they surrounded it, and as soon as the victim appeared he was struck down with axes. His cattle fell to Modjadje's share.

When I attacked the heathens with the Gospel, stating: "Whoso sheddeth man's blood by man shall his blood be shed," they were equal to the occasion, and started to strangle their victims with a loop. A very tall native was the executioner. He with his staff entered quite peaceably the kraal of the person they intended to kill. He drank beer and took snuff with him, then suddenly threw the loop round his victim's neck, his assistants caught the legs, and so they tugged him to and fro till he was dead, and having carried out their orders they went away roaring and laughing. The queen was a blood-thirsty monster, who felt neither pity nor mercy. She remained childless, and this is said to have been one of the causes of her sanguinary disposition. She always had a chancellor, who lived with her and was her principal adviser, but who generally was killed within, at most, two years, lest he spread the secrets he had discovered.

THE CONSTITUTION OF THE COUNTRY AND THE WHOLE SYSTEM OF GOVERNMENT

was quite peculiar. Every minor chief, according to the degree of Modjadje's favour, received a small piece of land, for which he had to pay a daughter, who passed for a wife of Modjadje, but in reality

was her slave. Consequently, according to this custom all the chiefs were closely related to each other. Modjadje distributed these numerous wives amongst her men. From time to time she also arranged great drinking-bouts at the chief kraal, at which her favourite men had free intercourse with her wives. The children of these were considered as Modjadje's children. To these women Modjadje was brutal to the last degree. She used to beat them with an iron rod, and found her principal satisfaction and delight in homicide.

Referring to her, the natives used this proverb: "She is like a cooked pumpkin," i.e., the exterior is cold, the interior glowing. So she was able to talk with a great show of friendliness to a person whose death she had already in view. This snake-like manner was also adopted by her chiefs. She never appeared in person in a meeting of the council, but communicated her views only by means of her chancellor. It was not allowed to any one of her indunas, not even to her chancellor., to approach her when clothed under penalty of death. I once noticed myself how much her chancellor was worried by having to take off and put on his rather thread-bare shirt when going to and coming from the queen. About ten steps from Her Majesty everyone had to creep, and this in a most doglike way. No contradiction was permitted, and every disobedience punished by death.

On account of her seclusion the oddest sayings arose. Rider Haggard's well-known Romance, entitled "She," treats of Modjadje. The Boers did not credit the existence of Modjadje The different tribes conceived the most horrible idea of her personality and manner of life. So it was supposed that her body was quite different from that of other human beings; that she was endowed with four breasts, long hair, and many other strange qualities. Her seclusion is said to have started with the following event. About 50 years ago a bastard appeared in Northern Transvaal, who pretended to be the son of the god Ralevimbo, and who roved about the residences of the great chiefs with a rifle and numerous followers. As tribute he demanded their daughters for wives, in which attempt he was partially successful. So one day he came to Modjadje with his retinue, and demanded to marry the young queen. Terribly frightened about this, the natives gave him as much beer as he wanted, till he was completely intoxicated; then they retired and left him. Meanwhile the queen had fled into a cavern. After that time she would not see any white face. To the white authority her sister, who resembled her in a most striking manner, was represented in her stead. This sister must have been beautiful in her youth: tall and slender, with a pointed nose, dark-blue eyes, and a light colour. Modjadje is said to have been still more beautiful.

In war-time every chief had to lead his chosen men to the chief kraal, where they were made fit for war by a witch-doctor, so that no bullet might do them any harm. In addition to this, everyone could at any time get a packet of medicine by paying for it, as a remedy against ghosts. This medicine consists of a powder, which was blown towards the ghosts.

HER WITCH-WORK AND ANCESTOR-WORSHIP.

About an hour's distance from the chief kraal, on a high mountain, an impenetrable thicket is found, in which Modjadje's chief witch-doctor and high priest resides. His duty is to make sacrifices at the three great feasts to the gods, i.e., the forefathers of the dynasty, who are buried there. This was done (1) just before they intended to pick the gardens; (2) at New Year, i.e., when they started to eat green mealies and the first pumpkins; and (3) in the beginning of the harvest.

The preliminary arrangements for such a feast were somewhat as follows: A great number of young girls in an entirely naked condition, carried big pots of beer to the aforesaid bush. In front of them went a number of men with horns, whistles, and drums, to give notice to the inhabitants of the country that the procession had started, so that everyone on the way might hide himself in time. Everybody who was seen by them on the way was murdered without mercy. They also took a black ox with them as a sacrifice. This animal was killed at the graves, and the best parts of the meat were handed over to the priest, who lived in a hut in the midst of the bush. This fellow also received part of the beer which was to be poured on the graves of the old kings. But very often they acted dishonestly towards the ghosts with the libation—drink. So one of my evangelists, who formerly had to act as a substitute in pouring the beer on the graves in this bush, told me that he only dedicated the dregs to the forefathers, and had the lion's share for himself. And when, through the effect of the enormous quantity he had drunk, he was unable to find his way back, he pretended that he was fuddled by the breath of the ghosts. The prayer the priest used in the act of pouring is worded something like this: "Mokakolo, Seale and Petole (these are the names of the former chiefs), look here! We bring you meat from our herds and beverage from our harvest; receive it and be ye joyful and merry. But now cause ye the country to be at peace, and unmolested by any enemy. Keep ye away all diseases from our fields, and give us wives and beer in abundance." When this act has been completed, it is brought to the knowledge of the country by beating drums and blowing of horns. Lastly, this was followed by a banquet to the gods, and a love-feast finished the ceremony. They eat and drink till all is finished. After the procession has again reached the capital, the members start piping and squeaking in every hollow and bush in a most melancholy way. Women and children hide themselves, for, according to their belief, these are the voices of the gods approaching them.

On the next day a big drum in the chief kraal proclaims either (1) the commencement of work in the gardens, or (2) the right to eat green mealies, or (3) the beginning of the harvest. The nearest village which is reached by the sound of the drum forwards the message to the next, and so the drumming noise goes through the whole country; at the same time they make a noise, whistle, and dance, that one might think the devil with his whole herd has burst forth.

Modjadje's tribe had no fixed religious system. They were bound to the belief in the ghosts of their ancestors. These they also tried to conjure up. They generally did it when they changed their dwelling. They then point out to the ghosts an abode, either a peg which they drive into the ground inside their hut, on which they pour the remnants of their beer as a libation; or a plant, of which they sometimes have as many in their court-yard as the deceased ancestors with which they are acquainted. Sometimes also they offer them as a dwelling a fine, smooth-skinned ox or another animal.

They also have a story about the creation, but it is rather vaguely outlined in parts. This indicates how dimly and uncertainly they think about this subject; but all the same the tale has points of resemblance with the biblical story. It runs as follows: Kobe has created the world through his son Kusane. Once upon a day he went to hunt with his son, and got very thirsty. There was no water in the neighbourhood and no kraals, but on a sudden they discovered an accumulation of rain-water on a tree. Kobe now asked his son Kusane to help him in ascending the tree. The son drove wooden pegs into the tree, so that the old man could mount. But as soon as he was on the tree Kusane pulled them out again, left his father, and went to the wives of Kobe that night. But when they the next morning perceived that he was the son, he fled. Now the natives hope for his return, and they say: "When Kusane returns war will cease; the assagais and axes will be turned into picks and ploughshares; the country will be in a state of peace, and all the chiefs will submit to him willingly and without any war."

As is the case with most heathen tribes, the witch-doctors, with their hocus-pocus, witchcraft, dice, and medicines, have the chief influence, so it is here. Nobody dies naturally; according to their belief he is put out of the world by witch-craft, called Boloi. The only question is to find out the guilty person, and this is done through the witch-dice, which, as a rule, have to turn the scale in difficult and critical moments of the lives of members of the tribe. These dice consist of the vertebræ of the different animals with which they consider they have a common origin. Thus Modjadje belongs to the pigs, others to the lions, tigers, elephants, etc. If the bone of that animal to whose family the probable thief, or murderer, or other offender, belongs, stands erect, he will be caught at once as the suspect. The accuser has the right to kill him, and Modjadje takes his property. But if the accused is very wealthy, he drives some head of cattle to Modjadje to persuade her to have her chief witch-doctor to reconsider the case. In this case the fault is generally laid upon another person and the first accused gets free. The witch-craft doctors have a wide knowledge of places and people; they perceive and know the locality from which their clients come from their pronunciation, as well as from their manner and behaviour. They also notice at once from the accusers' attitude whether they intend to spend much, and whom they want to be found guilty. In this manner it is not so very difficult for the witch-doctors soon to meet the wishes of the latter, and to entrap their selected victim. The whole business is, of course, quite a low fraud.

A most profitable sphere for these Kaffir doctors is Basutoland. I was once told by an assistant of a travelling doctor the way in which they cheat the poor, stupid people there. He said they provided themselves with beans growing in the Low Country, called "brand-boontjes," on the pods of which a reddish dust is found. The slightest contact with this causes a continual itching sensation, which is scratched until big blisters arise. With this dust they covered the stones at night-time, on which the men were going to sit the next morning when holding a council. The doctor, who has rested quietly during the night in this kraal leaves the next morning. After the men have occupied their seats to hold their council all start to scratch themselves. Then they get uneasy and apprehend the worst. Quickly the doctor with his assistant is called back to give aid, and to ease them of their apparent epidemic disease. The doctor looks exceedingly dubious at this sudden and, according to his diagnosis, very dangerous disease, as he intends to get as much as possible out of them. And for less than a nag or a heifer he is not able to offer any help. One by one they are attended to, he rubs the spots in question with a very expensive medicine, as he says, which, however, is nothing else than green soap. After this has acted for a while, he washes it off, and immediately the patient is cured. At this result all are greatly astonished, including the patient, while the doctor gains the horse or cow.

In a similar way all their medical cures are, with few exceptions, swindles. Most dangerous and demoralising is the medicine they use for destroying germinating life. Through this nearly 50 per cent. of the women are ruined. They also know different sorts of poison, some killing quickly, others very slowly. These they use to mingle with the food. And, as mentioned already, they sell medicines against ghosts, and to cure any disease of mind or body.

One of my colleagues and myself once carried out a fine practical joke on one of these witch-doctors, whom we met on a journey. The doctor had decked himself with medicine-bags in front and behind. My colleague said to me: "Look here, I will just cheat this fellow." Quickly he put a stone into his mouth, which made his cheek swell out, then he bent his head and started to complain to the doctor with a most pitiable face about excessive pains, and asked him for help. Willingly the doctor produced an ointment. But the patient said: "No, my friend; before I can trust you, you must tell me by your dice what kind of illness I suffer from." "All right," said the doctor, "but you must throw them yourself." My friend agreed, and he had to do it several times. A crowd of people had already assembled around us, and watched the proceedings. On a sudden the doctor declared in a solemn way: "Now I have got it; the cause is a fistula in the gums; you are a great smoker, and through permanent contact of the gums with the tobacco the fistula has been caused." "Is it truly what the dice tells you?" asked my friend. The doctor replied in the affirmative. Now the stone was produced, and my colleague said to the doctor: "Look here, my friend, this is the whole cause of the illness." The spectators all split their sides with laughing, and the poor old doctor withdrew with shame.

In nearly all risings of the natives the witch-doctors have a great influence. They either make their people believe that the weapons of their enemies will not stand the test, the rifles pouring out water instead of bullets, or they promise to make them invulnerable.

MANNERS AND CUSTOMS.

Polygamy still exists, but it is on the decrease since Rinderpest and Tick fever swept the cattle away, and since the Government adopted Law No. 3, regarding "the Regulation of Native Marriages." The legal marriage of a polygamist with one wife has also been conducive in checking this heathenish evil.

Circumcision is of a late date in Zoutpansberg, and it has been adopted to strengthen the chiefdom again; but last, not least, to make the most of it in money and cattle. The Bawenda and Maquamba have only adopted it a couple of years since. The performing of circumcision of the males, but especially that of the females—for even such a thing has been established—is an excuse for, and a stronghold of, all heathenish vice: drunkenness and fornication.

Infanticide still exists. In earlier days, twins, and those children who got the upper teeth first, were murdered, according to native law. This was not considered to be an injustice. But since the Government forbade it, it is only done secretly. Generally the old women, together with the mother, pour boiling water into the throat of the poor victim, and accelerate death by strangling. The corpse is thrown into an old pit, formerly used for burying mealies.

Abortion. The most horrible and widespread evil amongst natives is, as mentioned above, forced abortion by a purgative. Many women go to ruin or drag on their existence for months and even years before they recover, and in most cases remain childless.

Prostitution and Polyandry in their exact meaning do not exist among this tribe.

Birth. For days before the birth, the woman in labour is not allowed to eat anything. During the act itself all the old women of the kraal are assembled. As soon as the pains start the woman has to occupy now a half-standing, then again a half-kneeling posture. She has to embrace one of the women present, who has to assume the same posture, like two persons wrestling. And thus the child, as it were, is wrestled out. They do not think of giving the woman in labour relief by a good couch, or of doing anything to prevent the rupture of the perineum. After birth the child is left unseparated until the after-birth appears, and only then the umbilical cord is cut. This is the reason why so many umbilical ruptures occur. The child is washed at once with cold water, and the mother is now allowed to retrieve the loss in food. At the birth the woman in labour has to undergo a sort of confession by the old women, who tell her that she has to die, or that the child will not live if she does not confess

whether the child is from her husband, or whether she has been on terms of intimacy with others. If the latter is the case it is generally told. Shortly after birth the witch-doctor again has to show his art with the new-born child, and by his hocus-pocus and medicines he makes the child strong and vigorous. The name the child receives in the meantime is given according to events happening at this time; for instance, some were named "Mynheer," when I entered the country; others "Joubert," at the time of war with the Boers.

The Language is a mixture of several dialects of the Basuto tribes, as in early days many of the far-away living natives wanted to enjoy the blessings of Modjadje's rain-making. So people of all tribes and languages settled here: Balemba, Bawenda, Maquamba, Zulus, and Basutos. This tribe has mingled chiefly with the Bawenda, so that the Modjadje dialect has most coloration from the language of the latter tribe. For example:—

Tshewenda:	amba, to speak.	Modjadje,	apa.
,,	leshango, land.	,,	leshako.
,,	penga, to be mad.	,,	peka.
,,	tshembela, to walk.	,,	tshepela.

Sickness. From December to May, fever with its complications rages. In some years open and fetid abcesses are found on the legs of individuals.

Phthisis appears proportionally often, very likely on account of the change from the High to the Low Country, for this illness is found with very few women. Syphilis is not well known. Of Leprosy I happened to see only one case in 25 years. Taken as a whole, Modjadje's people live long; many reach a hundred years.

HER RELATION TO CHRISTIANITY.

In 1887 Modjadje permitted me to found a station in her country, and, as I was the only white person in the Low Country at that time, she handed over to me all sorts of things for repair for herself and her indunas: old knives, picks, watches, revolvers, etc. But when one of her headmen inclined to adopt Christianity, she caused him to be murdered. By 1884 a small congregation of converted natives had gathered about the Christian Chief Kashane, and he was murdered, with about 40 men, women and children. For about 10 years I then had to exist as a kind of under-chief, and paid my tribute to Modjadje, until in 1892 other occupants entered the country and also tried to settle in her territory. She opposed them and burnt down the dwelling-houses of the farmers, whereupon she was conquered and obtained a large location. Fear and difficulty in her advanced age caused by this war had distressed her to such an extent in mind and body that she died in 1895. In her last years she had a friendly mind to me and Christianity, for I was able to help her a great deal in the troubles caused by the war, and to assist in the matter of securing the location for her people. Her successor was

her sister, who had always represented her, but she also died soon after, in August, 1896; whereupon the present Queen Modjadje began to reign. She is about 30 years of age, and has a son. The former power and influence this tribe had has entirely disappeared, since they have been forbidden to murder promiscuously.

Out of this tribe I now have a congregation of about 1,300 members, eight out-stations with schools; on the main station are two white missionaries, a registered school of 230 children, with two white and four coloured teachers. A large cruciform church is filled on feast-days by over 1000 attendants. A brass band introduces the Sunday, and a church choir assists at divine service. All the buildings, which are substantial and comely, were erected by the Christian natives themselves without any extra pay from the Missionary Society. The whole of the station is situated between beautiful green plantations, so that it relieves eye and heart.

I have the best hopes for the Low Country in the future, for it is rich in natural deposits, both on and under the surface, rich in water and wood, and populous.

22—SUNRISE AND GROWTH.

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Experiments to ascertain whether there is any special growth at sunrise are lacking, and such a book as Osterhout's *Experiments with Plants, 1905*, does not suggest making any, either in connection with temperature or light effects upon plants. The following were carried out during February, March, and April, 1906, in a garden in Pretoria, Lat. 25° 45 S and Long. 28° 14 E, at a height of 4450 feet above the sea, and 270 miles from it. The mean temperature varied from 70° F in February to 62° F in April; the mean maxima were 82° F and 79° F for the same months respectively, and the mean minima 59° F and 47° F. The rainfall was 4.27ins. during February, 3.05ins. during March, and 0.52in. on 2 days during April. Cloudy days were few, and during the important tests, from March 23rd to April 23rd, the sky was overcast at sunrise on only two, and on one of these there were occasional gleams of sun. On 21 days the sky was cloudless as regards these experiments, on 5 it was overcast some time during the day, and on 6 there were detached clouds. A *Rambler Rose* grew 33 inches in 3 weeks and 19 inches in the two following weeks during the period of the experiments.

That some connection would be found between sunrise rays and growth was suggested by a wonderful cloud-phenomenon, which was seen at that hour on March 12th, 1905, from the deck of *S.S. Gaika,* when in Lat. 8° S and Long. 3° W, close to the Magnetic Equator. As the sun rose out of the water due E at 6 a.m., the sky was suddenly covered with myriads of cirrus threads as fine as those of a cobweb, and each one stretching continuously from true north to true south parallel to one another, and without break or irregularity of any kind. By the sun's action each particle of frozen moisture in the cirrus levels had been symmetrically brought into lines, so as to form a series of arches at right angles to the rays of light. At a higher level than the cirrus lines there were a few flecks of cirrus cloud drifting from north to south, but the lines had a movement of their own. As measurements with instruments proved, they swung slowly round as if endeavouring to keep themselves perpendicular to the sun. At noon the lines had thickened considerably, and half-an-hour before sunset there was a double set of them, one perpendicular, and the other parallel, to the incident rays. They were watched during the process of forming, and appeared to be evolved out of minute globules of cirrus haze. By no possibility could this have been the effect of wind, and it was the opinion of those who were taking the measurements that the arrangement of the globules into lines was directly due to the sun's rays.

This wonderful phenomenon was repeated on two consecutive days and was carefully studied in all its details, to see if it would throw any light on analogous cases in which a symmetrical arrangement of particles of matter takes place under the action of incident rays. In botany we have such a disposition of chlorophyll-granules on cell-walls which are perpendicular or parallel to the rays,

and it is thoroughly recognised that the intensity of the illumination controls the arrangement of the granules. How it does so is still a question, but it is more or less an accepted theory that living protoplasm has a directive property owing to which it can distribute the granules in the way which is most beneficial for the growth of the plant. Protoplasm cannot live without water, and in the absence of a sufficient supply it loses much of its power. Moreover, the arrangement of the granules during darkness is not the same as during diffuse or direct sunlight. Further, there is the alteration in the shape of the granules under varied illumination which has to be explained, and which so far has not been traced to any action of protoplasm. Flat, angular, polygonal tablets, as in the leaflets of *Funaria hygrometrica*, become hemi-spherical or spherical bodies, when direct sunlight succeeds diffused light. Are we straining the analogy too far in tracing a connection between the change of shape in chlorophyll-granules by sunslight, and a similar change in the cirrus particles, owing to which the lines became perceptibly thicker about noon?

We already have the hypothesis advanced that the vital force of the sun regulates the processes of synthesis going on in the cells where chlorophyll-granules are at work. To the vibratory energy of the blue and violet rays the decomposition and transformation of the carbohydrates are ascribed, while the less refrangible rays assist their formation from the raw materials. Protoplasm is unable to accomplish this without the aid of the chlorophyll-granules, and it is in them that the processes are carried on. *They* retain or extinguish those rays which might hinder the formation of carbohydrates, transform rays with short wave-lengths into those of longer wave-length, that sugar and starch may be more effectually manufactured; and, finally, effect the conversion of light into heat, and ultimately into latent heat. * It would only be a step further in the theory of synthesis under the action of sun's energy to ascribe to the same energy a directive influence upon chlorophyll-granules, similar to that which was seen at sunrise on March 12th controlling the distribution of the cirrus particles.

The following experiments were accordingly carried out to see whether any special influence was exerted upon chlorophyll-granules by sunrise rays, which could be detected during the growth of a plant. A strip of garden ground, which was practically virgin soil, was lightly manured with stable manure, and on Feb. 19th, 20th, 28th, and on March 6th, twenty-six rows, each 12ft. long, of *Dwarf Stratagem* peas, onions, beets, and lettuces were carefully planted. The rows ran north and south, and except for a low hedge of pomegranate and quinces 4ft. high and at a distance of not less than 3ft. from the rows, they may be described as unsheltered from the sun till about 4 p.m. Each plant was watched from the moment its leaves appeared above ground, and its position was entered on a large chart. By March 23rd considerable differences could be traced,

* *Natural History of Plants,* from the German of Anton Kerner, 1894, vol. I pp. 371-9.

which might easily have been attributed to the seed or to the soil had not records been kept of the amount of sunrise rays each plant had received. It was quite certain

1°. That wherever plants had received a greater share of the earliest rays than their neighbours, even though the distance between them might be only four inches, they had grown more rapidly.

In consequence of a difference of 18 minutes between the times the south and north ends of Rows I. and II. received direct sunlight, there was a marked difference between the peas there. There were four strongly-defined lines stretching diagonally across the rows, where growth had been stimulated by early rays which came through gaps between distant trees and out-houses, or through crevices in the hedge. Though the rays passed to the adjoining plants in less than 10 minutes, the latter were inferior, and never grew to as large a size.

2°. That rays which fell on ground after 8h. 43m. did not have the same effect upon growth as those previous to that hour.

Sunrise was at 6.25 a.m. about this time. Up to March 23rd no seed had germinated at the north ends of the rows, within the shadow cast by the hedge up to 8h. 43m. There was no exception to this, and the line of shadow at that hour could be distinctly traced by the line of growth.

The first result can most easily be explained by considering it as an effect of temperature, though it is remarkable that the loss of only 10 minutes of direct sunlight at this hour of the day should have caused such a marked difference in the growth of plants which were not more than three inches out of the line of the ray. We cannot, however, leave out of account the action of light in arranging chlorophyll-granules on cell-walls according as it is diffused or direct, nor the fact that the chloroplasts are most active when illuminated by the red, orange, and yellow rays of the spectrum.

Differences of temperature, however, will not explain the second result. Here the direct sunlight from 8h. 43m. to nearly 16h. was powerless to make the end seeds in 14 rows out of 26 germinate. But when, owing to the sun's increasing northerly declination, direct light came through a gap about 7h. 15m. and fell on the same portion of these rows, the seeds put up leaves. This occurred in numerous cases after March 23rd, and there could be no mistake about the observation.

With the view of obtaining further information regarding these two results, and of determining whether plants which were deprived of the sunrise rays up to 8h. 43m. would show any etiolation, or decreased action on the part of the chloroplasts, the following experiment was made.

On March 22nd a portion of Rows I. and II., in which the peas had received the same amount of the earliest rays, and were particularly strong and even in growth, was shaded off by an iron screen 2ft. 4ins. long and 9 inches high. It was fixed in the ground 7 inches

from the nearest plants, and made to slant outwards from them till the shadow just left their roots at 8h. 43m. Those which were 6 inches further off in Row I. had their roots in shadow till 8h. 6m. The leaves of all the plants were in sunlight about 18 minutes previously.

By March 26th six of the 7 peas belonging to Row I. were in flower, but only one of the 7 in Row II. On the 27th the pea in Row I, which had not flowered (No. 10) had begun to turn yellow. Its tendrils had no coil in them, and especially those highest up the stem, were hanging limp. By the 28th the condition of the plant was so bad that it was feared that it would die. No. 11 next to it was also turning yellow, especially on the south side, which received the sunlight 2 to 3 minutes later than on the north side. Its tendrils also had lost their coil. Both 10 and 11 were measurably smaller in every way than those next them, both in the dimensions of their stems and of their leaves. None of the other peas behind the screen were as yellow as 10 and 11, but all were distinctly smaller than those at the south end of the rows, which received rays as early as 6h. 45m. As it was important that 10 and 11 should not die, in which case the decay might have been attributed to bad seed, insects, or to soil, the screen was lowered before sunrise on the 29th, so as to allow them to be in full sunlight a little earlier. This was effected by sloping the screen outwards without otherwise altering its position. It is suggested that the change of colour was not an effect of temperature, but of distribution of the chlorophyll-granules on the walls of the cells under the action of light. This view is supported by the fact that No. 11 continued to turn yellow all through the 29th and 30th. The prejudicial action was not arrested suddenly.

The alteration of the screen allowed direct sunlight to fall on both 10 and 11 about three-quarters of an hour earlier, and as soon as the first ray touched the roots of 10 at 7h. 25m. on the 31st, the tendrils began to coil for the first time. The plant remained stunted and yellow, but from this onwards the chlorophyll began to return to the foliage, and there was never any doubt but that the plant would survive. Similarly No. 11 had become green and healthy by March 31st. It had received direct rays 4 minutes before No. 10 each morning. On March 30th there were stratus clouds at sunrise, and at 2 p.m. a heavy shower of rain fell, accompanied by some thunder.

So far, these experiments were in favour of the hypothesis that cutting off the early rays till after 8h. was prejudicial to such plants as peas, onions, lettuces, and beets; and that not only was the growth affected by variations in temperature, but that the chlorophyll-granules were being disadvantageously arranged for doing work, by the intense illumination they were subjected to during the day. It appeared as if the early rays were required to distribute the granules to the best advantage, and enable them to recover from the effects of the intense sunlight of the previous day.

A curious observation which had been made in a garden at Cape Town in March, 1905, seems to bear on this point. A large, oval grass plot was surrounded by a border of the Kei-apple plant, half of which was to all appearances dead, the stems being white and leafless, while the other half was green and luxuriant. The border had been replanted several times, but without any success. The points which appeared remarkable were these :—

> 1°. Every plant in the decayed portion was affected to a similar degree. There was no indication that any individual plant had been protected by its position from the mischievous action, whatever it might be.
>
> 2°. At each end of the dead portion there was a length of 6 feet in which the plants were very poor, but were not altogether leafless. Both of these lengths were on the south side of the luxuriant half of the oval. Their symmetrical arrangement could not be accidental, and suggested that the cause of the decay was one which was constantly and gradually changing its position from day to day.

On the morning of March 23rd the sunrise was being watched at 6h. 53m., and while the garden lay in the shadow cast by the Lion's Rump, the sunlight out to sea was moving shorewards, till it eventually came up the gently sloping ground to where the oval border was. At 7h. 37m. it reached that portion which was luxuriant, and three minutes afterwards it was diagonally across the grass plot, almost joining the ends of the decayed portion. Two feet out of the six-feet lengths at each end were in sunlight as 8 o'clock struck and the sunlight's further progress ceased. A shadow fell across the dead oval border and lasted till 9h. 50m. It was caused by a neighbouring house, and at 9h. 50m. it joined the two extreme points as if with a straight edge. The length of 6 feet at either end is at once the proof and the result of the gradual variation in the incidence of the early rays, owing to the sun's changing declination. The leafless state of the plants, it is suggested, was due to their being in intense sunlight from 9h. 50m. onwards; and without the rays of low refrangibility to re-arrange the chlorophyll-granules the stems turned white, indicating that the granules had withdrawn to the innermost cell-walls away from the mid-day glare. The chlorophyll bodies had not been deprived of the requisites for developing the green pigment, but the granules had accumulated on those surfaces which were least exposed to the bright light. An examination of several neighbouring gardens showed the action to be the same everywhere in the case of the Kei-apple plant. Wherever the early rays did not reach it, and it was in full sunlight for the rest of the day, its state was just the same. Cape local time is that of Long. 30° E, or 46 minutes before sun's mean time. This observation therefore elicits the fact that at sea-level, as well as at an altitude of 4450ft., plants which do not receive direct sunlight before 9h. 4m. in March (true time) are very prejudicially affected, while those that receive it as late as 8h. 6m. change colour. The withdrawal of the chlorophyll-granules to a position of 'apostrophe,' and the cessation of growth both of the peas at Pretoria and of the

Kei-apple at Cape Town, can be more readily accounted for as an effect of intense illumination rather than of temperature. These effects were prevented wherever sunrise rays fell on the plants.

Another plant which has shown itself to be susceptible to the early morning rays is the Scarlet Verbena. In this case 24 Verbena slips were planted in a circular bed in the garden at Pretoria. Eight of these were scarlet, and were planted together on the south-west side. Not one of them rooted, whereas the remainder did. Amongst the plants that succeeded was a scarlet one, and when it was observed that that portion of the bed where they had failed had been in shadow at sunrise, six more scarlet slips were cut from this one, and were planted in the same place, when the shadow no longer fell on it at sunrise. Four out of the six rooted. One of the two that failed was in the shadow cast by a pine-apple seedling till 8h. 30m.

During a successful experiment to try and revive some desiccated *Macrocarpas* an observation was made which seems to connect the foregoing results with the cloud-phenomenon of March 12th, and to show that they were due rather to the action of light upon chlorophyll-granules than to temperature. Three *Macrocarpas* forming part of a hedge 7ft high, withered from the effects of the winter of 1905. By September the foliage and epidermis were russet-red. An experienced local gardener pronounced it impossible to restore them by watering or by any other means. An examination of the roots proved them to be healthy, and it was determined to try and save the trees by the application of water to the epidermis. In order to obtain a constant drip upon the stems, bottles were tied near the top of each tree, neck downwards, and corked. A hole had been knocked in the bottom, and another had been drilled through the cork. When the bottles were filled with water from the bottom, a constant drip took place which could be regulated by a plug of wood in the cork. About 2 pints of water were allowed to fall on to the stems in this way during the 24 hours. All the trees revived gradually. New shoots were not put out, but the old branches and aciculated leaves turned first yellow and then green, showing, in the writer's opinion, that desiccation had resulted from too small a supply of water to the protoplasm of the cells, and from too much sun. It seems probable that the chlorophyll-granules were heaped up on those cell-walls which were parallel to the incident light, and as long as this continued the yellow colour remained. But when sufficient water once more reached the protoplasm vitality returned, and the granules resumed their functions under the influence of light. There were two sprays in particular which supported this view of the action going on within the cells. They were near the top of one of the trees, and turned the usual canary-yellow. They were watched for 13 days, and no sign of chlorophyll appeared. The branch to which they belonged was then separated from the rest, and it was found to spring from a node 2 inches *above* the drip of the water. This was the first instance of the kind. The bottle was accordingly raised, and within 48 hours the sprays turned green. It was considered in this case, as in that of the peas, which turned yellow

when the early rays were cut off and resumed their green colour when the rays were readmitted, that light acting upon the chlorophyll-granules, and not temperature, was the true explanation.

On March 27th the further experiment was made of screening peas from the time they were sown. It was also desired to eliminate the possibility of sunset or of reflected rays having vitiated the former results. Some of the seedlings in Rows I. and II. had been observed to have received more sunset rays than others, and also some reflected rays from a house window 20 yards away. Three more plots, each 5ft. long, were planted with selected seeds of *Dwarf Stratagem* peas, 4 to 6 inches apart, where they would receive the earliest rays, but no direct sunlight after 15h. 30m. Plots A and B were provided with iron screens, the former 10½ inches wide by 8 inches high, and the latter 14 inches wide by 9 inches high. The peas in Plot A, which were furthest from the screen, were arranged to receive the rays about half-an-hour before those nearest to the shadow thrown by the screen, while those actually in the shadow would not receive any direct rays till after 8h. 42m. The screen at the head of Plot B was perforated with 7 holes the size of a threepenny piece, that the effect of intermittent light, if any, might be watched. Plot C was used as a control without any screen at all.

At sunrise on March 28th the ground in Plot A up to within 18 inches of the screen was lit gradually from 6h. 50m. up to 7h. 3m. On April 2nd the first seed appeared above ground. It was the end seed (No. 1) furthest from the screen. Rain fell during the day, and on the 3rd the majority of the peas showed their leaves above the surface in all the plots. The first table gives the times of incidence of direct rays upon each plant in Plot A from April 8th onwards. No. 8 was just on the edge of the deep shadow; Nos. 3, 4, 7 had not come up. The next table gives the measurements which were taken on April 14th.

Plot A.—Times of Incidence of Rays, April 8—12.

Date.	1	2	5	6	8	9—10
April 8	6h 59m	7h 2m	7h 13m	7h 13m	7h 24m	not up.
9	7 7	7 9	7 11	7 13	7 24	"
10	7 7	7 9	7 13	7 13	8 0	"
11	7 6	7 9	7 13	7 26	8 18	"
12	7 0	7 15	7 15	7 29	8 18	"
13		some cloud at sunrise.				

Plot A.—Dimensions of Plants, April 14th.

No.	Stem. Diam. mm.	Stem. Height. mm.	Number of Leaves.	Number of Branches.	Number of Tendrils.
1	2	40	7	2	1
2	2	35	6	1	1
5	2	40	6	1	1
6	1	15	5	1	—
8	1½	25	5	1	—

On April 12th there was not the least doubt that, small though the differences were in the times of incidence, the peas varied greatly in the height to which they had grown and in the size of their leaves. No. 6 had come up after No. 8, and was much the worst of all. The remainder had come up within a few hours of one another, but were visibly smaller as they approached the screen. No. 8 was much smaller in every way than No. 5, and two of its five leaves were only just visible. The leaves of No. 5 were much inferior to those of No. 2. Nos. 9 and 10 in the shadow of the screen had not come up, nor had Nos. 3, 4, and 7. The three latter were accordingly dug up and examined. Two of the seeds were good, and one of them was germinating. The screen was removed before sunrise on April 13th, and direct sunlight admitted to the whole of the plot by 7h. 16m. in order to see whether any of the seeds 3, 4, 7, 9, or 10 would come up. They did not do so. After the screen was removed 11 weeds appeared within the area of the shadow, whereas none had appeared there previously though there were many in other parts of the plot.

Meanwhile the peas in Plot B were teaching exactly the same lesson. Growth was in proportion to the amount of early rays the plants received, and the direct light during the rest of the day did not equalise matters. But a curious result followed from perforating the screen. The two nearest peas to it received intermittent rays for some 6 minutes at a time between 8h. and 8h. 30m. During 9 days the leaves remained just visible above ground. There was no growth whatever. The holes were then stopped up, so that the peas remained in shadow till 10h. 30m. In 7 days' time no change in colour occurred but they were only 2 m.m. and 5 m.m. high respectively. Sunrise rays were then admitted to one of them, but not to the other. The latter is dead, the former is still alive, nearly 3 months afterwards, but is barely 5 m.m. high.*

These experiments and observations appear to be worthy of consideration. The exceptional circumstances under which they were carried out must be borne in mind, but, taken in connection with the remarkable effect of sunrise rays upon the cirrus particles in the sky on March 12th, they suggest that protoplasm in the presence of water may be a *medium* through which the vibratory energy of the rays is conveyed to the chlorophyll-granules imbedded in it.

The lesson taught by the Kei-apple border, confirmed by the experiments with vegetables and macrocarpas, and interpreted by the cloud-phenomenon which has been described, may possibly be that *the directive force lies in the rays of light*, and is not entirely inherent in protoplasm. I would remind you of the discovery of protoplasm, and of its behaviour in the water-weed *Vaucheria clavata*. It is between the hours of 8 and 9 a.m. that new protoplasm is always put forth by a movement of rotation and forward straining (Kerner). The little ellipsoid has a polarity, and always moves with the same end forward. Its first motion is towards the light, and

* It lived till Aug. 3rd.

as it moves it turns round its longer axis invariably from east to west, or in the direction opposed to that of the earth. It behaves as if it were a little magnet actuated by currents of electricity proceeding from our kosmic system.

The critical hour of 8h. to 9h. appears in a number of phenomena connected with the sun, for which we are still searching for an explanation. It is suggested that those botanists who can do so should specially examine the distribution of chlorophyll-granules on cell-walls from sunrise up to 9h. Should the result confirm the hypothesis which has been advanced to try and correlate the curious facts which have been described, we may hopefully look forward to a day when a direct connection will be proved, not only between the sun's energy, magnetic phenomena, and the running of sap, but between the sun's vibratory rays and even gravity itself.

23—NOTES ON SOME SOUTH AFRICAN CYCADS.

BY H. H. W. PEARSON, M.A., F.L.S.

(Abstract.)

Field observations have been carried on in 1905 and 1906 on *Encephalartos Friderici-Guilielmi*, Lehm., *E. Altensteinii*, Lehm., *E. villosus*, Lém., and on the "open-veld" form of Stangeria, which is possibly merely a variety of *S. paradoxa*, Moore. The full paper (see Trans. S.A. Phil. Soc., Vol xvi., pp. 341-354) contains a discussion of the results obtained, the more important of which are here summarized.

In *Encephalartos Friderici-Guilielmi* and in Stangeria subterranean branching plays a part in vegetative reproduction which is not less important than in many ferns with subterranean rhizomes.

The cones are lateral in *E. Friderici-Guilielmi* and in *E. Altensteinii*, and the growth of the stem is in both cases monopodial.

E. Friderici-Guilielmi, which is subject to strong insolation, cones much more freely than either *E. Altensteinii* or *E. villosus*—both, especially the latter, shade-species.

In *E. Altensteinii* cones are not infrequent on plants growing in more or less open positions exposed to sunlight. As far as is known, they occur very rarely, if at all, on plants in densely-shaded situations. A few observations support a similar conclusion for *E. villosus*.

It may be that other exceptional circumstances, such as are implied in cultivation, also act as a stimulus to the production of cones.

In *E. Altensteinii* branched specimens seem to occur only in illuminated situations, and usually, if not always, near water—conditions which are both favourable to nutrition.

There is a distinct probability that entomophily occurs in *E. villosus*. The position of the cones in Stangeria, with respect to the surrounding vegetation, points to the inefficiency of the wind as a pollinating agent.

24—THE GLACIAL BEDS IN THE GRIQUA TOWN SERIES.

By A. W. Rogers, M.A., F.G.S.

During the geological survey of the Hay district in 1905 a comparatively small thickness of rock near the top of the Griqua Town series was found to contain numerous boulders and pebbles shaped and scratched in the manner characteristic of stones that have received their final touches from the grinding action of moving ice. Their discovery gives evidence of the third known, but earliest, period of cold climate in South Africa, the other two being those represented by the glacial deposits in the Table Mountain and the Dwyka series.

These ancient glacial periods are extremely interesting from several points of view. First, they show that very far back in the earth's history the climate in the areas concerned was such that great accumulations of snow and ice were possible, and that consequently the world's climate of to-day may not be, on the average, hotter or colder than it was then. When the evidence concerns a period possibly older than the oldest known fossiliferous rocks of any country, its bearing on the physical conditions which have prevailed during the evolution of all the known forms of life becomes important. Then, again, the required explanation of the cold climates opens up great questions, which have yet received no probable solution. The fact that a rigorous climate would probably not be local in its occurrence, that it would not be confined merely to one district in this country, gives us a new means of correlating beds in distant areas.

At most places where the Griqua Town glacial rocks crop out they are very hard and dark brown or red in colour, owing to the large amount of iron oxides in them. There are several localities where the matrix is dark blue, in colour not unlike that of the Dwyka boulder beds in the south of the colony, but there is much cherty silica in it, which makes it break with a conchoidal fracture.

The dark blue rock has been found between Kort Kloof and Punt in Hay, on Good Hope in Barkly West, and at Dimoten and Monjana Mabedi, near Khosis, in the Kuruman district. The blue matrix is crowded with grains of quartz, and it also contains many small fragments of dark chert. The included pebbles and boulders are angular, subangular, or rounded, and they range up to two feet in length. Many of them are covered on one or more sides with striæ, in the manner characteristic of glacial boulders. Some of the stones are of the "facetted" type, that is, they have one or more nearly flat faces; in cases where there are two or more faces they may meet along a fairly well defined edge. These faces are well striated.

There are other facetted fragments, which were found to be especially abundant at Sunnyside in Hay, though they occur at many other places, but their faces are not striated, or they have very few and short scratches on them. These fragments are invariably pieces of chert, and their form is probably the result of fracture along joints before they were enclosed in the matrix.

Throughout a large part of the rock the pebbles and boulders are distributed without any discernible arrangement, but layers of conglomerate, two or three feet thick, made up almost entirely of well-

rounded pebbles, occur immediately below the unbedded rock at several localities, and thin, lenticular layers of gravelly rock were noticed in the unbedded boulder rock at Punt and Good Hope. Below the glacial horizon there is generally found a coarse iron-stained grit, several feet thick.

The boulders and pebbles are chiefly made of dark chert. Some of them are nodular lumps, usually discoidal or elliptical in shape, with a distinct banding parallel to the plane in which the two longer axes of the nodule lie. These nodules are often covered on their flatter sides with the glacial scratches. Quartzite and grit pebbles are not infrequently seen, and fragments of a white-banded marble, very fine grained, occur in the blue rock at Punt, Good Hope, and Monjana Mabedi. In the red and brown outcrops these limestone fragments are represented by cavities in the matrix partly filled with iron oxides; in the red rock the iron oxide is in the form of specular iron lining the cavity and filling it to a greater or less extent.

So far as my observations have gone, fragments of granite and other igneous rocks are not present in these beds, a striking point of difference from the other glacial boulder beds in the Colony.

The red and brown rocks certainly owe their colours to changes which have taken place subsequently to their deposition. In some of these rocks there has been an addition of iron compounds, but it is not yet known whether this access of iron is in all cases a surface phenomenon, i.e., that the iron has collected near the surface from the immediately underlying rock, or whether it has been brought from a distance. The fact that the more ferruginous and heavier varieties are particularly noticeable where the lower beds are hæmatitic jaspers, as along the west side of the Ongeluk-Witwater syncline, and the fact that the blue matrix has only been found where the lower beds are blue or brown, although there is no such change in the surface conditions as would account for the difference, make it probable that generally the increase in iron has not taken place at the present surface. In this connection it should be remarked that the processes by which the bulk of the Griqua Town beds became converted into ferruginous jaspers were completed at the time of the formation of the Dwyka boulder beds, for large pieces of rock, which very probably came from the Griqua Town beds, have been found in the Dwyka, and in Prieska and Hay the normal Dwyka still rests upon the ferruginous jaspers.

At two places, in a sluit on the west side of the Paling ridge, and near a dried-up fountain at Monjana Mabedi, the boulder beds have been found to be more thoroughly weathered than elsewhere, and they then have a most remarkable general resemblance to both the weathered glacial beds in the Table Mountain series in Pakhuis Pass, Clanwilliam, and to the Dwyka in its weathered state. The only obvious difference in the exposures is due to the absence of other than chert, quartzite and grit boulders in the Griqua Town boulder beds.

The glacial horizon has now been found to extend from near the Orange River in Hay to about 20 miles south of Kuruman, a distance

of some 115 miles from south to north. The width of the area is about 30 miles. It has not yet been found west of the Langeberg or east of the Kaap Plateau. In all cases it is succeeded by the Ongeluk volcanic series within about 30 feet. In the Good Hope outlier there are less than 12 feet of thin, bedded, dark quartzitic rock between the two, and the same is the case at Monjana Mabedi and Punt. At Juanana the intervening beds may be 30 feet thick. Generally there is a tract of low ground between the nearest outcrops of the Griqua Town and Ongeluk series, and it is only where hills made of the latter series rise sharply from the underlying beds that the succession has been clearly seen. The glacial beds have been found to underlie the Ongeluk series over a very wide area, and in nearly every outlier of the latter, the only exception being the Paarde Vley syncline, which has not been re-examined since the existence of the glacial beds was discovered, and there can be little doubt that the succession is a conformable one.

The source whence the chert and other rocks forming boulders in the glacial beds came is still unknown. The frequence of chert nodules should prove to be of material help in settling the question, but at present such nodules have not been described from South African rocks. The only similar nodule known to me from any other rock was shown me by Mr. D. J. Haarhoff, M.L.A., in Kimberley in April, 1906, and he says it came from the "blue-ground" of the Kimberley Mine. This nodule is so like those mentioned above that I am inclined to believe that they all came from the same formation. The mode of occurrence of the chert in the Campbell Rand beds is not like that indicated by the form of the chert nodules in the glacial beds.

As to the age of the Griqua Town beds, there is nothing new to say. All recent writers on the subject are agreed that these beds are older than the Cape System of the south, but there is a difference of opinion as to the probable lapse of time between them. If, with Passarge (1) and Hatch and Corstorphine (2), we regard the unconformably overlying Matsap beds as the equivalents of the Table Mountain series of Lower Devonian or Silurian age, the Griqua Town beds may not be very much older than those periods. We know that after the deposition of the Griqua Town beds there took place a great outpouring of volcanic rocks in Cape Colony, and that both the volcanic rocks and the underlying sedimentaries were subjected to earth movements and prolonged denudation before the Matsap beds were laid down. This correlation of the latter with the Table Mountain series is, however, of doubtful value. It is based chiefly on two facts; first, a certain degree of lithological resemblance, and, second, the fact that both are older than the Dwyka series, and rest unconformably upon still older rocks.

As to the lithological resemblance, when we have stated that both groups are largely made of quartzites, with occasional thin bands of pebbles and isolated pebbles, we come to the end of the similarity.

(1) Die Kalahari, 1904. (2) The Geology of South Africa, 1905.

In colour, in modes of weathering, and in general appearance, the two groups are not alike; the Matsap beds are, on the average, coarser in grain than the Table Mountain beds, and the purple-mottled tints of the great bulk of the former are foreign to the latter; the Matsap beds do not give rise to the peculiarly-curved, wind-worn masses of rock, with accumulations of iron oxides and silica in some parts and a loose, sandy texture in others which have been observed in the Table Mountain sandstone, from the Pondoland outcrops to the westernmost exposures in Calvinia. The surface of the Matsap areas is covered with large and small blocks of quartzite, with rounded corners; the rock breaks down into its component grains much less readily than the Table Mountain sandstone does; in the Langebergen of Griqualand West the ground on the top of the mountains is hard, sandy soil between the outcrops and boulders of quartzite, while in the Langebergen of the south coast and other mountains made of the Table Mountain series, the interstices between outcrops are filled with loose white or black sandy soil.

The chief objection to the correlation is to be found in a comparison of the structural features of the north and south of the Colony. In the south the earth-movements which produced the ranges made of the Table Mountain series took place long after the deposition of the Dwyka series, and there is a sequence of conformable rocks from the base of the Table Mountain series into the Karroo formation. In the north there is a great gap between the Matsap beds and the Dwyka. Near Piljaar's Poort there is an outlier of the normal northern type of Dwyka till lying between the forked ends of one of the Langeberg group of hills, and one of the chief constituents of the boulders is the Matsap quartzite; there is no doubt that the northern Langebergen were in very much the same condition during Dwyka times as they are in to-day. They have probably lost something in altitude by denudation, and new valleys have been cut in them, but they stood in the same relation to the older rocks east and west of them as they do now, and they do not appear to have suffered any further crumpling. Except that these earth-movements which affected the Matsap beds in the north took place in Pre-Dwyka times, we have no direct evidence of their date as compared with the southern rock-systems, but a further comparison of the geology of the two regions will throw more light on the question. The Matsap beds are certainly some thousands of feet thick; four thousand feet can easily be accounted for in the Langebergen, near Pad Kloof, and the top is not known. These beds originally stretched over a considerable part of Hay and southern Bechuanaland, at least as far as the Paling-Gamagara and Matsap ridges, which are outliers of the formation; a great part of this sheet of rock must have been removed in Pre-Dwyka times, for at Piljaar's Poort the outlier of Dwyka till mentioned above very probably rests upon the Griqua Town beds which crop out in the immediate neighbourhood, between the Dwyka and one of the Langeberg ridges. Now, if the Matsap beds are taken to be the equivalents of the Table Mountain series, the earth movements that crumpled the northern strata and the denudation which removed

such large masses of the northern rocks must have taken place during the Bokkeveld-Witteberg times, represented in the south by some 5000 feet of rock. This seems to me improbable, and the only way to avoid the difficulty is to regard the Matsap beds as older than the Cape system.

Assuming that this argument is good, the Griqua Town beds, which are overlaid unconformably by the Matsap beds, must be very much older than the Cape system, and though there is no direct evidence, they may quite well be of Pre-Cambrian age.

25—NOTE ON *FUSICLADIUM:* AFFECTING APPLES AND PEARS IN CAPE COLONY.

BY J. B. POLE EVANS, B.A., B.SC., PLANT PATHOLOGIST.

There are two distinct diseases affecting apples in the Colony. The one under discussion in this note affects the leaves, twigs, and fruits of both apple and pear.

The fruit, the most important article from the grower's point of view, is attacked at all stages of development, but especially after the petals have fallen and the fruit is no bigger than a marble.

To such an extent is the young fruit affected at this stage that it usually shrivels and drops off.

The appearance of the disease to the naked eye is the same in all cases; usually round, rough, dark, olive-green. and velvety patches appear on the leaves, twigs and fruit.

The fruit, if it continues to grow in spite of these spots, nearly always does so at the expense of cracking.

Cutting such an apple across shows that internally it is quite healthy.

The other disease, a far more serious trouble, is known locally as "Bitter Pit."

Externally this disease is only seen on fruit which is nearing maturity, and, what is more serious still to the exporter, appears on apparently sound apples, after they have been packed in cold storage.

To the naked eye this disease appears first as smooth, dark-green, and slightly sunken depressions usually towards the upper end of the apple. Later on these depressions turn brown, then black in colour, and entirely disfigure the whole apple, and, further, when the apple is sliced open it is spotted here and there with masses of dry brown tissue.

With regard to this latter disease we shall have nothing further to say here.

FUSICLADIUM.

As far back as 1888, Professor MacOwen attributed the disease on certain leaves and fruits of the Saffraan Pear to the fungus Fusicladium dendriticum, Fckl. He also reported that he had occasionally noted the same fungus on Apples in the Colony.

As some doubt has recently arisen with regard to this disease, I was invited to visit Cape Colony during the month of March and investigate the matter.

Some of the results of this investigation are put forward in the present note, the object of which is to show that there are two specific fungi present in Cape Colony, namely *Fusicladium dendriticum*, Fckl, attacking Apples, and *Fusicladium pirinum*, Fckl., found on Pears.

The general appearance and occurrence of the disease in the Colony has been dealt with by Mr. Lounsbury in the Cape Agricultural Journal, No. 14, of 1905, so that without travelling over old ground we shall confine ourselves to the miscroscopic investigation.

For this investigation, a large supply of material, including diseased leaves, twigs and fruits of both Apple and Pear collected from various orchards in the Colony, was forwarded from time to time by Messrs. Lounsbury and Dewar, Government Entomologists at Cape Town and Grahamstown. In addition, while in the Colony in March, material of diseased Pear was obtained at Worcester, Paarl, Stellenbosch and Cape Town, and of diseased Apple at Stellenbosch.

All the material examined was found to be producing abundant conidia from the disease spots. From the nature of these conidia and their conidiophores, it was evident at once that we were dealing with two distinct fungi. In spite of this fact, a sharp look-out was kept to see if infected Apple material ever showed signs of being infected with the fungus found on the Pear, or Pear material to be attacked with the fungus found on the Apple. No indication of this was found in any of the examinations.

By some authorities the fungus occurring on the Apple is considered to be identical with that on the Pear; by others they are regarded as two distinct species.

To constitute a specific difference between two plants, we must be able to point to some morphological character by which we can distinguish the one from the other. A reference to the figures of these two fungi will, I think, clear up any further doubt regarding them.

FUSICLADIUM DENDRITICUM, FCKL.

In Figure I., Plate, p. 268, is shown a section through a small disease spot of *F. dendriticum* on the Apple, of the variety known as the "Late Bloomer." It will be seen that the mycelium bursts through the epidermis, and a succession of spores is constricted off in a continuous fashion.

The ripe conidia (Figure II. a.) when sown in water soon germinate (Figure II. b.). The spore always becomes septate, and gives rise to the germ tube (Figure II. b. and c.), which eventually bears secondary spores.

FUSICLADIUM PIRINUM, FCKL.

In Figure III., Plate, p. 268, is shown a section through a disease spot on the Pear, of the "Saffraan" variety. For some little time the mycelium remains covered by the epidermis, through which it sends up here and there, stout conidiophores, which have a studded

or warted appearance, and may not unfrequently be branched. From these conidiophores the somewhat spindle-shaped spores are given off.

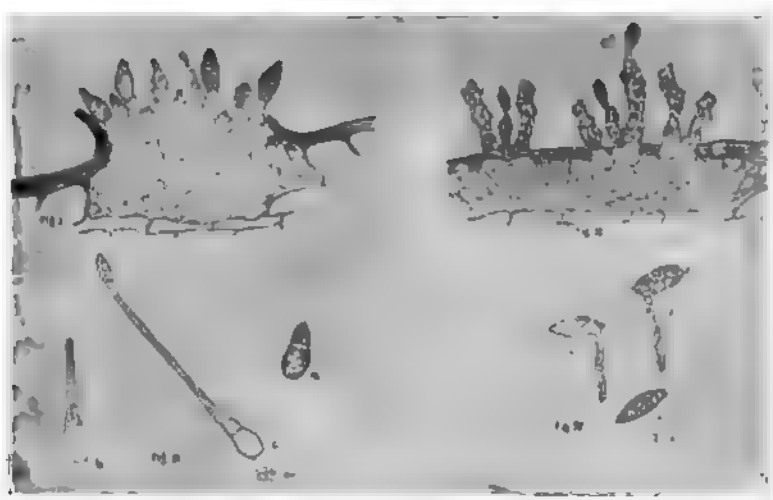
These spores (Figure IV., a., b., and c.) unlike those in the case of the Apple-fungus, never become septate; and, further, when they germinate, the germ tube arises at right angles to the length of the spore, instead of growing straight out, as in the case of *F. dendriticum*.

From this examination we are led to conclude that the disease, long known amongst Apples and Pears in Cape Colony, is due to two distinct (but closely related) fungi.

That causing disease amongst Pears is due to the fungus *Fusicladium pirinum*, Fckl., while that attacking Apples is caused by the fungus *Fusicladium dendriticum*, Fckl.

These fungi are readily distinguished, the one from the other, under the microscope, and they are identically the same as those which cause the disease known in Europe, Tasmania, Canada, America, and Australia, under various names as *Fusicladium*, Scab, Scurf, Black Spot, and Cracking.

I. & II. *Fusicladium dendriticum*, Fckl. III. & IV. *Fusicladium pirinum*, Fckl.



Fusicladium, Figures I., II., *a.*, *b.*, *c.*; III., IV., *a.*, *b.*, *c.*

26—THE PETROGRAPHY OF THE ROCKS SURROUNDING THE DIAMOND-PIPES OF THE KIMBERLEY DISTRICT.

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I.—INTRODUCTION.

The manner of occurrence of the diamond bearing rocks of the Kimberley district has been so often described that it is unnecessary to do more than refer very briefly to this part of the subject. As is well known, the diamonds occur in a peculiar brecciated rock, the so-called "Blue Ground," which fills a number of vertical pipes or necks, of a somewhat cylindrical form. The mode of origin of these pipes has given rise to a great deal of controversy, but it is now generally agreed that they are of volcanic origin, although the precise type of vulcanicity which gave rise to them is still undecided. The literature of the diamonds themselves and of the rock which contains them is an extensive one. The whole subject is treated exhaustively in Mr. Gardner Williams's great monograph on the "Diamond Mines of South Africa," and in a section contributed by the same authority to "Science in South Africa," the official handbook of the South African meeting of the British Association in 1905.

The object of the present paper is rather to give a short petrographical description of the rocks which surround the diamond-bearing pipes, and, in particular, of the rock types which have been exposed in the deep shafts at the Kimberley and De Beers Mines. The former has now reached a depth of 2520 feet, and the latter 2040 feet. The Bultfontein, Dutoitspan and Wesselton Mines are of much less depth, not exceeding 750 feet.

The specimens on which the following descriptions are based have been selected from two collections presented by the De Beers Co. in 1905 to the Mineralogical Departments of the Universities of Oxford and Cambridge. The specimens preserved at Cambridge were placed in my hands for determination by Professor Lewis, and Mr. Hutchinson, and I have to thank Professor Miers, of Oxford, for kindly permitting me to examine certain of the Oxford Series unrepresented in the Cambridge collection. A few of the specimens were collected by Mr. A. Hutchinson, Demonstrator of Mineralogy in the University of Cambridge, during the course of a visit to Kimberley in the autumn of 1905, when facilities for examining the De Beers Mine were afforded him by the Company. In what follows, individual specimens will be referred to by means of the numbers attached to them by the De Beers Company.

Although so much has been written on the diamonds themselves and the rock in which they are contained, there are very few references in the literature to the petrographical character of the rocks

surrounding the diamond pipes. Besides Mr. Gardner Williams' works, already cited, the following may be specially referred to:—

BONNEY. On some rock specimens from Kimberley, South Africa. Geol: Mag: 1897, p. 497.

BUTTGENBACH. Quelques observations sur les champs diamantifères de Kimberley. *Ann. Soc. Geol: Belgique.* Tome XXXII. 1905. *Memoires,* p. 3.

ROGERS. *Geology of Cape Colony.* 1905. Chapter IX., p. 331.

HATCH AND CORSTORPHINE. *Geology of South Africa.*

HARGER. The Diamond Pipes and Fissures of South Africa. *Trans: Geol: Soc: South Africa,* VIII. 1905. p. 112.

Numerous further references will be found in the works above cited, and in the catalogue of printed books, etc., relating to the Geology of South Africa, by Miss M. Wilman *(Trans: S.A.Phil. Soc.)* Vol. XV., part 5.

II.—GENERAL DESCRIPTION.

It is unnecessary to give any detailed account of the superficial deposits of the area surrounding the mines: it must suffice to say that the soil appears to be thin, and is described as of a red colour; it is probably of a lateritic character, derived from the immediately underlying basic igneous rocks. A layer of what is described as limestone is widely distributed over the surface of the district. This appears to be of the nature of travertine or calc-sinter (the calcareous tufa of some authors). At all the mines except Bultfontein, the surface below the soil is composed of a thick bed of a rock, which is commonly spoken of as basalt, varying in thickness from 50 to 100 feet. This is underlaid by some 200 or 250 feet of black carbonaceous shale, and below this again comes a representative of the well-known Dwyka Conglomerate, which is here very thin. These sedimentary rocks scarcely require petrographical description, and no thin slices of them have been prepared.

Below the conglomerate in the Kimberley and De Beers Mines we have about 400 feet of a somewhat decomposed igneous rock, commonly known as melaphyre. Then comes another series of sediments; 400 feet of quartzite, followed by 260 feet of shale, according to Williams. As we shall see in a subsequent section, this broad division scarcely holds good on close examination, and, indeed, the distinction between shale and quartzite is here purely arbitrary; both rocks have very similar mineralogical composition, and the differences depend chiefly on the relative sizes of the constituent particles.

At a depth of about 1400 feet in both Mines there begins the great series of acid igneous rocks, the quartz-porphyries of Williams. As we shall see later, this series is by no means uniform, but includes several different petrographical types. At Kimberley this series

extends down to 2470 feet, from which depth comes another specimen of a sediment of somewhat peculiar character. At 2500 feet we reach granite, and the greatest depth represented by the specimens in our possession is 2520 feet. In the De Beers Mine, on the other hand, granite is reached at 1920 feet, so that it appears that the upper surface of the granite is here very uneven, rising 600 feet in about a mile. The presence of a sedimentary rock immediately above the granite suggests that this is a buried land surface, and extreme unevenness is a common character of land surfaces composed of denuded archæan or igneous complexes, e.g., the Lewisian gneiss, and the gneissose area of Brazil, in the neighbourhood of Rio de Janeiro. The other mines, Bultfontein, Wesselton, and Dutoitspan, do not reach a greater depth than 750 feet, so that they throw no light on this question.

In the latter group of Mines the upper part of the series shows some variation in detail, but the general succession is very similar. The differences chiefly occur in the rocks above the melaphyre; in the diagram given by Williams, quartzite is shown both at Bultfontein and Dutoitspan at a much higher horizon than elsewhere. We shall return to this question later on.

Since the Kimberley Mine is the one which has up to the present reached the greatest depth, it may for our present purpose be taken as typical, and will be described first, and in considerable detail. Some of the rock types, however, show better development elsewhere; in such cases description will be deferred till the mine in question is treated of.

Since the ground surface around all the mines is at practically the same height above sea level, varying only a few feet on either side of the contour of 3990 feet, it will be convenient in all cases to use the surface as a datum line, and to speak always of depths below this generalised surface. Since the depths given appear to be approximate, correct to only 10 feet or so, no appreciable error will be introduced, and the descriptions will be more intelligible than if heights above sea-level were used.

III.—PETROGRAPHICAL DESCRIPTIONS.

1. KIMBERLEY MINE.

The present surface of the ground at the Kimberley Mine consists of material which is collectively described as debris, having a total thickness of 30 feet, overlying 5 feet of red soil, which is probably of a lateritic nature. Below this we come to the usual basalt, which is here 50 feet thick, rather below the average. The specimens of basalt from this locality (201) (a) are much decomposed, while excellently fresh examples of what is undoubtedly the same rock come from other mines, and notably from Wesselton, so that consideration

(a) Numbers in brackets refer throughout to the original numbering of the specimens as supplied by the Company.

of this rock type may profitably be deferred for the present. Underlying the basalt are 250 feet of black, carbonaceous shale (202), which is certainly of Karroo age, and probably represents the Upper Dwyka Shale (b) of Cape Colony. Below it comes a thin representative of the well-known fossil boulder-bed, the Dwyka Conglomerate (203), which has here dwindled to a thickness of only 10 feet. These rocks need no further reference here.

Below the conglomerate we come to the next great development of igneous rocks, which is about 400 feet thick. This is the rock referred to by Gardner Williams and others as melaphyre (204, 205, 205a). It is an amygdaloidal, non-porphyritic rock, which is considerably decomposed, so much so that determination of the ferromagnesian minerals is difficult. The rock varies a good deal in texture and structure, since it occurs in very thick masses, and the inner parts appear to be somewhat coarser than the margin. The structure, apart from the amygdaloids, is essentially that of a coarse-grained volcanic rock, and it is apparently not holocrystalline, although decomposition has proceeded so far that it is difficult or impossible to determine the original nature of the interstitial matter.

The dominant minerals are a plagioclase feldspar and green chloritic pseudomorphs, representing some member of the ferromagnesian group. The feldspar occurs in idiomorphic, somewhat elongated prisms. The majority show twinning on the albite law, and often Carlsbad twinning also. The extinction angle, measured on the albite twinlamellae, rarely exceeds 5°, so that the feldspar may be regarded as oligoclase. In a few cases a somewhat higher angle indicates andesine, a few sections show Carlsbad twinning only, and these prisms are rather shorter and stouter than the others, so that a little orthoclase may be present. This point is somewhat doubtful.

The ferromagnesian minerals are unfortunately very much decomposed, being chiefly represented by green chloritic pseudomorphs. Many of these pseudomorphs enclose, however, a few fibres of a pale or colourless actinolitic hornblende, of the character usual in this mineral when of secondary origin, from the uralitisation of augite, and a few crystals of comparatively unaltered augite may also be seen. It it clear, therefore, that the original mineral was augite, which has undergone the usual cycle of changes, being first converted by uralitisation to actinolitic hornblende, and this in its turn to chlorite.

Some specimens of the rock show a certain amount of interstitial quartz, and in places it is clear that the last substance to crystallise was a eutectic of quartz and feldspar, as is so common in the more acid members of the dolerite group.

There is a good deal of iron ore in small scattered grains, including both magnetite (or ilmenite) and pyrites, and apatite is very abundant in minute needles. There are also a certain number of idiomorphic crystals of a pleochroic yellowish green epidote, which may be an original constituent, but is more probably secondary. As

(b) Rogers. *Geology of Cape Colony*, p. 147.

before stated, the original character of the small amount of interstitial matter is indeterminable, but probably little if any glass was originally present.

Amygdaloidal vesicles seem to be more common near the margin than in the centre of the mass. They are filled with concentric layers of chlorite, calcite, quartz, and chalcedonic silica, in indeterminable order.

This is apparently the rock which was determined by Stelzner as "olivine-diabase," but I have been unable to find any olivine or any mineral which can be supposed to represent olivine in the specimens at my disposal. One or two of these also show a fair amount of quartz, and it is unlikely that olivine would occur in such a rock. Large masses of sub-basic and basic rock of this type often show a good deal of variation in silica percentage, and a small increase in this respect is sufficient to prevent the formation of orthosilicates of the olivine group. The absence of the mineral in a few slices only is therefore inconclusive. It must be confessed, however, that the general characters of the rock suggest a distinctly more acid type than that to which continental petrologists are in the habit of applying the terms olivine-diabase and melaphyre. The latter, indeed, is defined by Rosenbusch as more or less equivalent to his labradorite-porphyrite, which is an essentially basic rock. However, the material in our possession is insufficient to fully decide this question. It can only be stated provisionally, and subject to modification, that the rock appears to be an intermediate lava, with affinities to the hypabyssal quartz-dolerites. However, it is probably more acid than the majority of these, and cannot strictly be referred to any accepted rock type. So far as the feldspathic constituent is concerned, the rock shows some affinity to the mugearites of Skye described by Harker (*), which are essentially oligoclase-rocks, with subordinate orthoclase. However, in these Scotch rocks augite is quite subordinate to olivine and iron ores, whereas in the Kimberley rock olivine is perhaps absent, and, at any rate, not abundant, while augite is the dominant ferro-magnesian mineral.

Below the "melaphyre," at a depth of 740 feet begins another series of sedimentary rocks, which has a total thickness of some 660 feet in the Kimberley Mine, and over 700 feet at De Beers. The section given by Gardner Williams shows 400 feet of quartzite above, with 260 feet of shale below, but our specimens from various depths indicate an alternation of these two types of sediment, as shown in the table (fig. A.), (206b., 206k., 206g., 207, 207b.).

A specimen of the quartzite from a depth of 1000 feet (206b.) consisted originally of well-rounded grains of quartz and feldspar, together with compound grains or small pebbles of various fine-textured, siliceous rocks. The feldspar is mostly orthoclase and microcline, and this and the rock fragments together make up at a rough estimate 10 per cent. of the whole. There are also a few crystals of a deep reddish yellow, isotropic mineral, which is probably

(*) Tertiary Igneous Rocks of Skye. *Mem. Geol. Survey,* 1904, p. 264.

perowskite. The rest of the rock consists of clear quartz, with the usual fluid pores.

The cement is entirely of clear quartz, and is in crystalline continuity with the quartz of the grains, so that grain and cement make up one individual, which extinguishes as such. The result is a mosaic of irregular-shaped quartz crystals, in which the outlines of the original grains are clearly to be distinguished. The rock is thus a very fine example of a typical quartzite, and it bears a very strong resemblance to stiperstones quartzite, † the basement bed of the Ordovician in West Shropshire. From the appearance of the grains it is evident that they have been derived from an area of metamorphic crystalline rocks, probably gneisses and granulites.

The specimen from a depth of 1200 feet (206k) is of quite different character. It is composed of smaller and much more angular fragments, which consist almost exclusively of quartz, embedded in a large amount of interstitial material, chiefly finely-divided mica, which is probably derived from the decay of feldspar under the action of weathering agents. The general character of the rock indicates somewhat different conditions to the last: it is probably derived from a granitic or gneissose complex under such conditions that the feldspar was decomposed and formed a fine argillaceous sediment, in which the quartz grains were embedded.

The specimen from, at, or near the 1300 feet level (206g.) is on the whole very similar in character to the last, but it includes rather more feldspar, together with some white and brown mica; the chips of quartz are still more angular, and suggest extremely rapid deposition, so that they were buried by the succeeding layers of sediment before any considerable amount of attrition had taken place. When examined under a high power the interstitial matter appears to be almost exclusively micaceous.

So far as regards their petrographical character, these rocks were originally feldspathic sandstones or arkoses which have been cemented into hard, lustrous quartzites of varying degrees of fineness. In some cases a rapid alternation of coarse and fine layers produces a well-marked lamination, so that they are often spoken of as shales, but the so-called shales are of essentially the same composition as the quartzites.

From the small amount of evidence at our disposal, it appears that this sedimentary series has been formed by the rapid denudation of a series of crystalline rocks, probably of a gneissose character. As we shall see later, the rocks which have been reached at the deepest levels of the shafts at the Kimberley and De Beers Mines are quite able to supply the kind of material here seen, and its source is probably to be found in the rocks of this series. It is perhaps dangerous to draw any conclusions as to the conditions under which they are formed, but what evidence there is points to deposition at a rapid rate in the immediate neighbourhood of a region of great denudation.

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† Harker, *Petrology*, p. 229, Fig. 2.

Petrography of Rocks.

A. THE ACID VOLCANIC SERIES.

Below the sedimentary rocks last described there is found another great series of igneous rocks, which, though much decomposed, appear to be on the whole of a distinctly acid character. The examination of numerous specimens shows certain points of resemblance in almost all cases, but still it is possible to distinguish two more or less well-defined types, which, as a matter of convenience, are here described as amygdaloid and quartz porphyry respectively. The differences are probably more apparent than real, and are more conspicuous in hand specimens than in thin slices. Speaking broadly, however, we may say that the amygdaloidal rocks contain few phenocrysts of quartz, while in the non-vesicular types this mineral is abundant in the porphyritic condition.

Our collection contains a good many specimens of these rocks from different depths, and from a consideration of these it is evident that the amygdaloid and the quartz porphyry occur in alternating beds or flows. The total thickness of the whole group is very great, amounting at the Kimberley Mine to about 1070 feet. At the De Beers Mine it is less, since the surface of the granite is here about 600 feet higher.

Although these rocks are here treated of under two separate headings, it must be clearly understood that there is every transition between them, and some of the specimens are so much decomposed that their original character is very doubtful.

(a) *The Amygdaloid.*

In a hand-specimen (208a, 208b), this is a pale, greyish green rock, fine in texture, and with a somewhat streaky appearance. It contains very abundant rounded or oval vesicles, filled with dark grey or white minerals. Examinations of slices show that the rock has undergone so much alteration as to make determination of its original character difficult, if not impossible.

It contains abundant porphyritic crystals, which have the characteristic form of feldspars, and are now represented by pseudomorphs of somewhat varying character. Many of them are more or less silicified, consisting of an aggregate of quartz, white mica, and some pale green chloritic substance, which shows very weak birefringence. The flakes of white mica usually show a distinct arrangement along two sets of planes, more or less at right angles, presumably the cleavage planes of the original feldspars. It is quite impossible to determine the original character of the feldspar, since no part of the original substance seems to remain.

The ground mass is of a peculiar character, consisting of a very fine-textured aggregate of quartz and feldspar: it shows the peculiar patchy structure known as micropoecilitic, which is defined by Harker as follows*:—"This consists of minute feldspar crystals with no orderly arrangement, enclosed in little ovoid or irregular areas of

* *Petrology,* 3rd Ed., 1902, p. 163.

quartz, the whole of the quartz in such a little area being in crystalline continuity." This structure is very characteristic of lavas which have undergone silicification, as has clearly happened in this case.

Some specimens show in the ground mass many well-formed rhombs of dolomite, which somethimes encroach on the feldspar phenocrysts, but do not appear to be derived from them; it would rather seem that they have originated in the ground mass, and have pushed aside the decomposing feldspar during their growth.

Vesicles are very numerous, but are rarely more than 3 or 4 *mm.* in diameter. They are filled with concentric layers of quartz, chlorite, calcite, and dolomite, and possibly some feldspar and zeolithic minerals.

Whatever the original character of this rock may have been, it is at any rate of volcanic origin, and in places the structure suggests that it may be something of the nature of an agglomerate, and not a true lava-flow. The specimens available are hardly of sufficient size to allow of the formation of a decided opinion on this point, but it is at least a possibility to be considered. A careful examination of the thin slices with a pocket lens yields no definite evidence. It should also be borne in mind that a simulation of clastic structure is often induced in viscous lavas by a kind of brecciation during flow. The question of the original character and origin of these amygdaloidal rocks must be left an open one.

(b) *The Quartz-Porphyry.*

The non vesicular type in a hand-specimen (209g, 209r, 209u, 211) is a rock of very crystalline appearance, and of the prevailing greenish grey tint which is so common in this series. It shows abundant phenocrysts of clear, glassy quartz and white, somewhat opaque, feldspar. Under the microscope the porphyritic character is conspicuous, and perhaps the most striking feature is the extraordinary manner in which the quartz phenocrysts have been corroded by the groundmass, so that they assume remarkable forms. This is a very common feature of the more acid hypabyssal and volcanic rocks, but is seldom so strikingly exhibited as in this case. This phenomenon is apparently due to the varying solubility of the quartz in the magma under different conditions of pressure.

In the intratelluric stage, where the pressure is high, quartz separates out in well-formed crystals, but in the effusive stage the pressure is decreased, and the quartz becomes more soluble, so that it is again partly dissolved by the magma. The peculiar forms are due to the varying solubility of the quartz in different crystallographic directions. *

The feldspars of this rock include both orthoclase and plagioclase in approximately equal proportions. Both occur in large, tabular crystals, which have often undergone a certain amount of magmatic corrosion. This is perhaps most strongly marked in the case of the orthoclase.

* See Penfield, *Trans. Conn. Acad.*, 8, 1889, p. 158.

The extinction angle of the plagioclase, measured on the albite twin lamellae, ranges up to about 22°. Its index of refraction does not differ much from that of orthoclase, so that it is probably albite.

The rock contains no phenocrysts of ferromagnesian minerals, but there are a very few small irregular crystals of a partially-decomposed iron ore.

The groundmass is microcrystalline, consisting of quartz, feldspar, and a good deal of pale green chlorite. Its general appearance is distinctly suggestive of silicification, as it is micropoecilitic, with a tendency in places to a microspherulitic structure. In some forms vesicles are absent, in other quartz-bearing specimens a few vesicles occur, and, as before stated, every transition can be traced to the highly-amygdaloidal type.

The foregoing description is principally taken from the freshest specimen, which comes from a depth of 1840 feet in the Kimberley Mine (208b), and probably approximates most closely to the original character of the rock. Other specimens are much more altered, and in particular many have undergone a high degree of silicification, so that both phenocrysts, vesicles and ground mass are converted into a mosaic of clear, granular quartz. A good deal of calcite is also often present.

The rocks described in the two preceding sections must be regarded as forming one continuous series of a volcanic nature, but it is not clear whether some of the non-vesicular types are true lava flows. It is possible that some of them may be of the nature of sills or other intrusive masses injected into a previously-existing series of lavas. There is not sufficient evidence at our disposal to decide this point, which can only be settled by an examination of the sections on the spot.

B. BASIC DYKES.

At various depths in the acid volcanic series there are found rocks of a much more basic character, which are referred to in the field notes supplied as dykes. These specimens come from the Kimberley Mine, at depths of 1520 feet, 1840 feet, and 2160 feet respectively. They differ very markedly from the surrounding acid volcanic rocks, and present some special points of interest. The three specimens vary to a certain extent among themselves, but they have sufficient features in common to suggest a genetic connection.

The freshest example comes from a depth of 1520 feet (222), and is a rock of peculiar nature. Its macroscopic appearance is that of a slightly porphyritic, dark-coloured rock of distinctly basic appearance, with no visible feldspar. Under the miscroscope it is seen to consist almost entirely of colourless pyroxene and a green chloritic mineral, with only a little interstitial feldspar, and the merest trace of quartz.

The ferromagnesian mineral clearly occurs in two generations, both as phenocrysts, and constituting the bulk of the ground mass. The crystals of the first generation are idiomorphic, usually in very well-formed, eight-sided crystals, which often show polysynthetic and

interpenetrating twins. The mineral, when fresh, is colourless in thin slices, and its double refraction is low, giving interference colours not higher than yellow or orange of the first order in a slice of the normal thickness. The extinction is oblique, ranging up to 45°, so that the mineral belongs to the monoclinic system. It is therefore to be identified as one of the colourless members of the augite group, diopside or fassaite. Partly intergrown with the augite in parallel position, and partly occurring in independent prismatic crystals is a pale green chloritic mineral, possessing the characters of bastite pseudomorphs after a rhombic pyroxene. This is probably the mineral described by Bonney *, and by him referred rather hesitatingly to enstatite. Feldspar crystals of the first generation are entirely absent, but large crystals of ilmenite, showing the characteristic bar-structure, probably belonging to the intratelluric stage.

The ground mass consists chiefly of an aggregate of small prismatic crystals of the same pyroxenes, with a certain amount of interstitial feldspar, and, as before mentioned, a very small amount of quartz. The feldspar is much decomposed, and it is difficult to determine its original character. However, a careful examination, both by daylight and in artificial light, has failed to reveal any albite-twinning, except in one or two cases, and it is clear that the most of the feldspar must be referred to orthoclase.

It is somewhat difficult to assign this rock to its type. The very small proportion of feldspar, and the fact that this is orthoclase and not plagioclase, serve to distinguish it from the porphyrites and normal dolerites. Perhaps it can be most satisfactorily classified as a member of the lamprophyre group. According to Rosenbusch's definition †, it must then be described as vogesite.

The other two examples of dyke-rocks (222c, 222d) differ from the preceding in showing a higher proportion of feldspar, especially plagioclase and quartz. They approach much more nearly to the normal dolerite type, and, as is common in this group, the last constituent to crystallise in the ground mass is a eutectic of quartz and feldspar. They may be quite safely described as quartz-dolerites, and their macroscopic appearance confirms this view.

We have no evidence concerning the age-relations of these basic rocks to the acid series in which they occur, but they are probably subsequent to, and intrusive in the latter, and this supposition is confirmed by their greater degree of freshness.

C. LOWER SEDIMENTARY SERIES.

Below the acid volcanic series comes another small development of sedimentary rocks, which in the Kimberley Mine appears to be about 30 feet thick. It is represented in our collection by one specimen only, from a depth of 2470 feet (220). This is a heavy, black rock of crystalline appearance, which shows conspicuous and rather irregular bedding.

* *Geol. Mag.*, 1897, p. 499.

† Rosenbusch, *Elemente der Gesteinslehre*, p. 239.

Under the microscope it is seen to consist of an alternation of layers of very fine-grained quartzose sediment and lenticular patches and streaks of crystalline calcite.

The quartzose bands consist essentially of very minute chips of quartz, and probably feldspar, with a good deal of mica, both colourless and brownish: there is also a considerable amount of black, carbonaceous matter along the bedding planes. Much calcite is present in scattered crystals. The calcareous layers are usually more or less lenticular in shape, and are composed of crystals of calcite (or dolomite) showing secondary twinning. The whole rock shows distinct signs of crushing, and might almost be spoken of as foliated parallel to the original bedding planes.

So far as the origin of this rock is concerned, two explanations are possible:—

(a) It may be a fine-grained sediment, containing pebbles of limestone, which have subsequently been squeezed out of shape and flattened by pressure.

(b) The calcareous matter may have been in the form of spheroidal or ellipsoidal concretion, due to segregation in the original rock, and afterwards recrystallised under pressure, perhaps accompanied by thermal metamorphism to a certain extent.

All we can definitely say is that the rock is a sediment, containing both siliceous and calcareous matter, which has been subjected to a certain degree of metamorphism, so that it has been crushed and more or less recrystallised. The thermal metamorphism is probably due to the overlying volcanic rocks, while there is nothing to indicate the source of the crushing.

D. THE GRANITE.

Below this sedimentary rock, down to the greatest depth represented in the collection, viz., 2520 feet (215) is found a rather pale, grey granite, which in places shows a somewhat gneissose structure. It has already been pointed out that the granite is reached at a considerably less depth in the De Beers Mine, indicating either a very uneven surface of denudation, or else intrusion of a very irregular mass. This last supposition is unlikely, since the sedimentary rocks within a few feet of the granite show only a feeble degree of thermal metamorphism, so far as can be judged from the small amount of material at hand. It is much more probable that the upper surface of the granite represents an ancient buried landscape, as in the case of the Mount Sorrel granite and other pre-triassic rocks of the English Midlands. * However, it must be admitted that this is almost pure speculation, founded on very insufficient evidence.

It so happens that specimens of granite from the De Beers Mine are much less decomposed, and show somewhat greater variety than those from Kimberley, so that they will be treated of more fully later on.

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* Watts, *Geogr. Journal*, June, 1903.

Fig. A.

Depth from Surface	Original Numbers	Cambridge Numbers	Thickness	
	201		50	Basalt
86				
200	202		250	Shale
336	203		10	[illegible]
300	204 205		400	Melaphyre
525	205 a			
740				
1000	206 b			Quartzite
1200	206 k 207 207 b		660	and
1280-1360	206 g			Shale.
1400				
1520	222 208 a 225			
1560	211			amygdaloid
	208 b 209 g			and
1840	209 u 222 d		1070	
2160	209 r 222 c			Quartz- Porphyry.
2470				
2500	220	20	30	Sandstone
2520	215 224 d	21 25		Granite

E. SUMMARY.

The succession of the rocks forming the walls of the diamond-bearing pipe in the Kimberley Mine may be conveniently summarised in the following table, which is compiled partly from data supplied with the specimens and partly from the sections given by Gardner Williams in the British Association Handbook; where any discrepancy existed, the figures given in the manuscript list of specimens have been accepted.

The table shows the depth from the surface at which the specimens were obtained, the original numbering as supplied by the Company, the approximate thickness in feet of each type of rock. The right-hand column gives the accepted petrographical description of each rock, for comparison with the previous literature. The diagram is drawn to a scale, viz., 1 centimetre = 100 feet, or approximately 250 feet to 1 inch.

2. DE BEERS MINE.

It appears from the sections given by Gardner Williams that the general succession of rock types here is identical with that in the Kimberley Mine, and the thicknesses also are very similar. The upper shale is a trifle thinner, 204 feet instead of 250 feet, and the sedimentary series below the "melaphyre" is about 60 feet thicker, so that the top of the acid volcanic series is at practically the same level. It has already been mentioned more than once that the upper surface of the granite is here met with at a much higher level, viz., at 1920 feet from the surface, instead of 2500 feet, so that the volcanic series is here much thinner, only 540 feet, instead of 1070 feet.

Under these circumstances, since the petrographical character of specimens from similar horizons in both mines is practically identical, it is unnecessary to give any further details, so far as regards the rocks overlying the granite. Since, however, the granite itself is in much better preservation, and shows greater variety in the specimens from this mine, it will here be described in detail. So far as regards the other rocks, a table is appended, similar to that given for the Kimberley Mine.

A. PETROGRAPHICAL DESCRIPTION OF THE GRANITE.

In hand-specimens (113, 113b, 114b) the granite is a pale grey rock of moderately coarse texture, even-grained, and non-porphyritic. It shows clear, glassy quartz, white feldspar, and a slightly greenish mica. In some specimens a few flakes of silvery white mica are also to be seen. The freshest specimen of all is one from a depth of 2040 feet in the De Beers Mine, collected by Mr. A. Hutchinson, and from this the following description is taken. The other specimens are similar, except for a greater or less degree of decomposition.

As before stated, the rock consists of quartz, various feldspars and mica, with only a small amount of accessory minerals. The

quartz occurs as a sort of mosaic of more or less rounded crystals, which are often enclosed in allotriomorphic crystals of feldspar, and it is clear that the quartz has crystallised for the most part before the feldspar, as in the Shap granite and elsewhere.

Fig. B.

Diagram- Section of De Beers Mine

Depth From Surface	Original numbers	Cambridge numbers	Thickness	
63	100 b 100		63	Basalt
273	100 a 101 101 a		204	Shale
				Conglomerate
658			385	Melaphyre
1000	103		722	Quartzite
1200	103 a			
1280	103 c			
1320	103 e			
1360	102 d			
1380				
1400	111 115			Amygdaloid and Quartz Porphyry.
1440	115 a 111 a			
1480	111 d			
1520	108 o			
1680	108 g			
1720	A.H.			
1840	108 m			
1920	113			
2000	113 b 114 b			Granite
2040	A.H. A.H. A.H.			

The Symbol A.H. indicates specimens collected by Mr. Hutchinson

The feldspar is very variable in character; it includes orthoclase and a little microcline, and a good deal of plagioclase; the latter shows indices of refraction in different crystals, both higher and lower than that of quartz, so that the range of composition is apparently wide.

The mica is of a greenish-brown colour, and strongly pleochroic. It is in parts more or less completely converted into the usual pale green chloritic decomposition product. Some slides show a little colourless muscovite. There is a small amount of magnetite, and crystals of a greenish-yellow pleochroic epidote appear to be original constituents.

Some specimens show a certain amount of parallel orientation of the minerals, especially as regards the mica, and it appears that the general structure is slightly gneissose. Whether this structure is primary or superinduced by pressure it is impossible to say, but there is not much evidence of foliation in the specimens examined, except in one case (224d) from the deepest level in the Kimberley Mine, 2520 feet, where there has evidently been some kind of shearing or thrusting movement, so that the decomposed feldspar has been broken up and crushed, while the quartz grains are almost unaltered; however, a few of the latter also are shattered. The flakes of mica have been squeezed between the hard quartz grains, and some show good examples of strain-slip-cleavage. (Ausweichungsclivage). This is a purely local phenomenon, and has not affected the mass of the rock.

Associated with the normal granite there are also some examples of pegmatites, of much coarser texture. The best specimen (114b) is composed chiefly of large crystals of a white feldspar, up to 2 or 3 inches across, with clear, glassy quartz, and dark mica in nests and patches; there is no visible muscovite, as in so many pegmatites. The feldspar is somewhat milky in colour, and shows very well-developed twinning on the albite law, with very numerous striations on the *c* cleavages. The extinction in small fragments is nearly straight, so that the feldspar must be identified as oligoclase.

Some specimens differ from the foregoing in being chiefly composed of pink feldspar instead of white, and small fragments of this under the microscope show the characteristic cross-twinning of microcline. Some quartz is present, but no mica. Thus there are two somewhat different types of pegmatite characterised by oligoclase and microcline respectively. However, transition types between these extremes can be recognised, and the whole of them probably belong to one phase of intrusion.

3. THE BULTFONTEIN, DUTOITSPAN, AND WESSELTON MINES.

At the present time these mines have reached a much smaller depth than is the case at the Kimberley and De Beers Mines. The deepest of this group is Dutoitspan, but even this only reaches about 750 feet from the surface. Sections of Bultfontein and Dutoitspan are given by Gardner Williams, * but as regards Wesselton we have

* *Science in South Africa*, p. 323.

not sufficient data to construct a similar diagram, since the specimens are few in number, and the limits of each rock-type are not stated.

At Bultfontein and Dutoitspan the general succession in the upper part, above the Dwyka conglomerate, is very similar to that already described, but below this level the thicknesses seem to be very different. The pre-Karroo sedimentary series appears to be reduced to about 150 feet, and volcanic rocks come in at from 550 to 600 feet from the surface. In the diagram given by Gardner Williams these rocks are labelled "melaphyre," but they have nothing in common with the rocks so-called above the sedimentary series. As we should naturally expect from their position below the quartzite, they clearly belong to the acid volcanic type, and they show in great perfection the micropoecilitic structure which is so characteristic of these rocks in the other shafts, and with these they are clearly identical.

The specimens of "basalt" (201, 100, 100b, 304, 402a, 405) from all the mines are very similar, in composition and general structure, though some are slightly coarser in grain than others. The rock is apparently holocrystalline, and consists essentially of feldspar, augite, and olivine. The latter mineral is abundant, so that the rock is of a distinctly basic character.

The feldspar occurs in large idiomorphic prismatic crystals, which invariably show twinning on the albite law, and generally also on the Carlsbad law. The extinctions are somewhat variable, but the majority show angles of 35° to 45°, so that the feldspar clearly includes basic labradorite and bytownite. Zonary banding is not conspicuous.

The olivine forms rounded, colourless grains, showing the usual irregular cracks, and in some cases serpentinisation has just begun, but most of the grains are almost unaltered.

Both the foregoing constituents are enclosed in typical ophitic fashion by large plates of colourless augite, which show good cleavages and extinction angles up to 45°. This augite is perfectly normal, and calls for no special remark, except that the ophitic structure is more than usually perfect.

The only accessories commonly visible are small flakes of a rather pale brown pleochroic biotite and small crystals of iron ore, which are probably ilmenite, since some of them show slightly translucent spots.

From the evidence at our disposal it is impossible to determine whether the rock in question is of an intrusive or extrusive character. Considering its petrographical characters alone, it appears to be more closely allied to the intrusive types than to the lavas. Some of the coarser varieties present a striking resemblance to the intrusive olivine rocks which occur in the Carboniferous Limestone of Derbyshire, and, apart from any knowledge of their field relations, would be unhesitatingly described as typical olivine dolerites, using the latter term in its modern sense, as a substitute for the older term, diabase, of British petrographers. Included in the collection are one or two rather finer-grained specimens, which are of more strictly basaltic

aspect, showing intersertal rather than ophitic structure. The occurrence of these two slightly differing rock-types may be explained in either of two ways. The doleritic type may form sills intruded into basalt flows in a later phase of activity, as in the Tertiary igneous series of N.W. Europe; or, alternatively, the whole may form parts of one phase, consisting of lava flows of considerable thickness, so that the inner parts of individual flows may have taken on characters resembling those of the hypabyssal rocks.

Mr. H. S. Harger* seems to imply, without explicitly stating the fact, that the whole of this series is intrusive, although he calls some of the rocks basalts, and the petrographical character of the rocks on the whole favours this idea.

So far as can be judged from the specimens in our collection, the general succession of the rocks in this group of mines, viz., Bultfontein, Dutoitspan, and Wesselton, is the same as at Kimberley and De Beers, although, as before stated, the thicknesses are very different. At Dutoitspan the melaphyre appears to be very thin indeed. It would therefore cause needless repetition to describe the specimens in detail.

4. BOULDERS.

Included in the collection are three specimens of boulders, one labelled (409) "Open Mine, Bultfontein," the other two (516) "470 ft., Dutoitspan."

One of the latter is of no particular interest, being a very ordinary oligoclase—augite rock, probably belonging to the "melaphyre" series. The other two, however, are worthy of particular description.

The boulder from Bultfontein (409) is of a rounded form, seven or eight inches in diameter, and much decomposed for some distance from the surface. Its central parts, however, are fresh, and show a coarse texture and general greenish colour. The most conspicuous minerals are olivine, green pyroxenes, brown mica and pink garnet. In a slice the dominant constituent is seen to be olivine, which is partly serpentinised, and shows "mesh-structure" in great perfection. The pyroxenes include both rhombic and monoclinic forms, which are fresh and colourless, so that they may be described as enstatite and diopside respectively. There is also a small quantity of grass-green pyroxene, probably the chrome-bearing omphacite referred to by Bonney and others.

The garnets show only the very faintest pink tinge in a good light; they are quite isotropic, and full of the usual irregular cracks. Each is surrounded by a shell of a greenish brown colour, and having a kind of dusty appearance.

Enclosed in this shell, and scattered through the mass of the garnets are abundant small octahedral crystals of a yellowish or reddish brown mineral, of high refringence and isotropic. This is undoubtedly a spinel, and probably one of the chrome-bearing varieties, such as picotite. The shell surrounding the garnets also

* *Trans. Geol. Soc. South Africa,* VIII., 1905, p. 112.

encloses abundant small crystals of a colourless mineral, probably a pyroxene. These shells are of less regular structure than the so-called kelyphite borders, which are so common in round garnets, but they are undoubtedly of the same nature. The biotite occurs in large plates, and calls for no special remark.

This rock agrees in mineral composition with the special type of enstatite-augite-peridotite, to which the name Lherzolite* is applied, although it contains more garnet than the original rock from the Pyrenees.

The other interesting boulder, from Dutoitspan (516) is of a very different nature. It consists essentially of plagioclase-feldspar, a peculiar form of pyroxene, and a good deal of iron ore. The general texture is coarse, but between the large crystals there is a small quantity of interstitial ground mass, so that, strictly speaking, the rock is porphyritic.

The feldspar builds large, tabular crystals, usually quite idiomorphic, and showing strongly-developed twinning on the albite and pericline laws. The twin lamellæ are broad, as is often the case in basic feldspars. The extinction angles range up to 45°, although the majority are about 30°. Investigation by means of the quartz wedge shows that the vibration direction lying nearest to the twin-lamellæ is the axis of greatest elasticity, so that the feldspar belongs to labradorite and bytownite, and not to anorthite, as suggested by its general appearance.

The pyroxene includes two distinct varieties, which are intergrown in the same crystal. One is quite colourless, with oblique extinction at a high angle, as in normal diopside. The other form shows a very good example of diallage structure, having rows of minute inclusions parallel to the basal plane.

Some twinned crystals show the resulting "herring-bone" structure very clearly. As a consequence of this, the hand specimen shows strong schillerization. The diallage has a general yellowish brown colour in a slice, and its extinction is much masked by interference. There is a good deal of iron ore in large, irregular plates.

The small amount of space left between the large idiomorphic crystals is filled by a beautiful eutectic of quartz and feldspar, and in many cases the feldspar of the eutectic can be seen to be in optical continuity with the large crystals.

This rock may perhaps be most satisfactorily described as an augite-porphyrite, although the amount of ground mass is so small that it might be regarded as a gabbro.

IV.—SUMMARY AND CONCLUSION.

The general succession of the rocks through which the diamond-bearing pipes have been formed, is thus seen to be on the whole very simple. At the lowest level yet reached we have a granite of unknown age. Resting on this is a thin sedimentary bed, and then a great thickness of acid volcanic rocks, which are compared by Rogers

* Rosenbusch, *Gesteinlehre*, p. 173. Harker, *Petrology*, p. 95.

to the Beer Vley volcanic series.* The overlying quartzites and shales are also considered to be of pre-Cape age; the "melaphyre," which next succeeds, is compared to the Zeekoe Baard amygdaloid, which is also of pre-Cape age. Here there occurs a great gap in the series, since the whole of the Cape formation is absent, and the thin representative of the Dwyka conglomerate, of Lower Karroo age, rest directly on the pre-Cape volcanic rocks. The basalt is in all probability of Karroo age.

The general results of the foregoing petrographical study of the rocks surrounding the diamond-bearing pipes, and the nomenclature adopted may be summarised in the following table, which also gives the maximum and minimum thickness observed in different cases.

Minimum thickness.		Maximum thickness.
2	Soil, calc-sinter and debris...	30
18	Basic igneous series, basalts and dolerites ...	63
200	Upper Dwyka Shale	250
3	Dwyka conglomerate	10
0	Intermediate igneous series	394
82	Pre-Cape quartzites and shales	722
?	Acid igneous series with basic dykes ...	1070
	Granite and gneiss.	

The nomenclature here used is purposely left as general as possible, since it is quite impossible in most cases to say definitely from an examination of hand-specimens and slices alone whether a given rock is of a hypabyssal or volcanic nature, and, in point of fact, the distinction between these two classes is a very artificial one. Large masses of lava often assume distinctly hypabyssal characters, on account of somewhat slower cooling, and narrow dykes often consist of rock having typical volcanic structure, e.g., some of the great augite-andesite dykes of the north of England.

The evidence in this case is meagre, and no stress can be placed on it, but it may at any rate be said that none of the igneous rocks seen in these sections, exclusive, of course, of the granite, show any features which are inconsistent with volcanic origin. They can, however, hardly all be part of one great series, since they must cover an enormous interval of time, owing to the great gap in the succession below the Karroo series, if we accept the correlation of these rocks given by Rogers. The acid and intermediate series may be connected although they show no points of resemblance, but the basic series belongs to a much later period.

The diagram on page 288 shows the results arrived at in a graphic form. It is compiled partly from the published works of Mr. Gardner Williams, and partly from information supplied with the collection of specimens.

* *Geology of Cape Colony*, p. 341.

Fig. C.

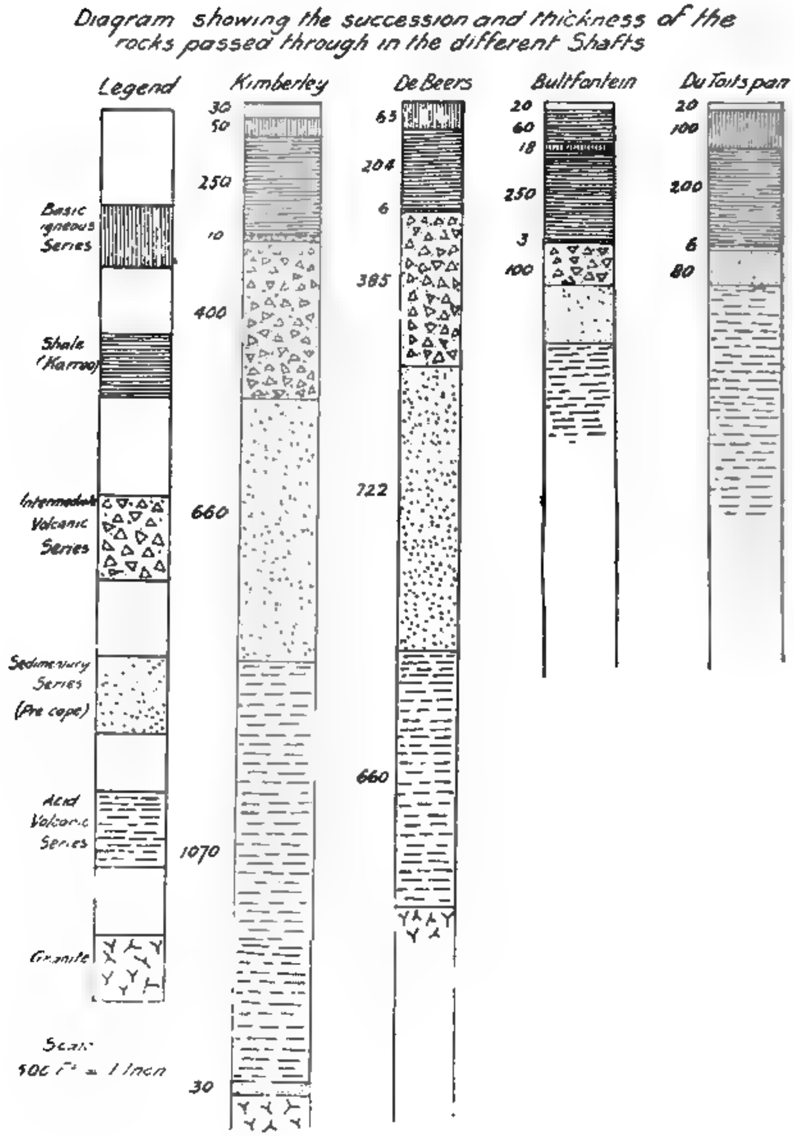


Diagram showing the succession and thickness of the rocks passed through in the different Shafts
Legend
Kimberley
De Beers
Bultfontein
Du Toitspan
Basic igneous Series
Shale (Karroo)
Intermediate Volcanic Series
Sedimentary Series (Pre cape)
Acid Volcanic Series
Granite
Scale 500 Ft = 1 Inch
30
50
250
10
400
660
1070
30
65
204
6
385
722
660
20
60
18
250
3
100
20
100
200
6
80

27—THE SOMABULA DIAMOND FIELD OF RHODESIA.

By F. P. Mennell, F.G.S.
Curator of the Rhodesia Museum, Bulawayo.

The last few years have inaugurated a new era in the history of the South African Diamond deposits, inasmuch as rich bodies of diamantiferous ground have been located at great distances from localities which have previously been worked successfully. The group, of which the Premier mine is the best known member, is the most striking example of this extension of area, but the centre of gravity of the diamond-mining industry seems to be gradually shifting northward, and the opening up of the interesting deposit of the Somabula Forest, so far North of any other known occurrence, foreshadows the development of an important branch of the industry in the Cinderella of the South African provinces, as Rhodesia has been not inaptly termed.

No detailed or authentic description of the Somabula field has so far appeared. The writer briefly referred to the occurrence of a remarkably gravelly deposit West of Gwelo in his "Geology of Southern Rhodesia," and ascribed its formation to the Tertiary period, a course which appears fully justified by more recent and detailed investigation. He had already seen diamonds and other gems from the locality, but had not been made aware of their source. Last year he made an examination of the ground on behalf of the South African Option Syndicate, who hold a large area on the field, and who have just erected plant for producing diamonds on a large scale. The reports of their preliminary operations will have shewn that a rich deposit of good quality stones has been opened up. A large quantity were disposed of at a price which works out at £3 17s. per carat, and a smaller parcel, sold more recently, fetched £6 per carat. The following notes, for permission to publish which I am indebted to the Syndicate, are intended to give some idea of the geological and mineralogical features of the field, of which I hope a much more detailed account will be given at an early date.

The diamond area may be described as a tongue of the Somabula Forest, stretching along the central plateau of Rhodesia from the Uvungu River for about seven miles in the diretion of Gwelo. The beds of which it consists are undoubtedly younger than the Forest Sandstones, as shewn by their numerous pebbles of agates derived from the lavas interbedded with those rocks, but they are probably not very different in age, and may perhaps be regarded as the uppermost portion of the Forest Sandstone series. They directly overlie the granite of the watershed, on to the apex of which they extend, but further down the Uvungu River the ordinary Forest Sandstones are met with. The general sequence appears to be :—

	(5) Surface rainwash, etc., chiefly redistributed gravel and sand (often absent)	say 10 ft.
Somabula Beds	(4) Red and white sands	say 40 ft.
	(3) Gravel, with partings of clay, etc.	say 40 ft.
	(2) White micaceous sand	30 ft.
	resting unconformably upon	
	(1) Granite.	

The top of the upper sandy beds is not seen, but the thickness given is probably well within the mark. The levels of the granite bedrock also vary considerably, and the beds themselves tend to assume a lenticular shape, so that it is impossible to give more than a rough idea of their proportionate development.

The UPPER SANDS, which have been entirely removed by denudation from some of the ridges, and from all the lower ground, are sometimes clayey and stained red by iron oxides, and sometimes fine and white. In a shaft at one spot on the slope of a ridge an actual thickness of 16 feet was passed through before reaching the underlying gravel. It may be stated, however, that so heavy an overburden is met with on few parts of the diamondiferous area.

The GRAVEL itself is composed of beautifully-rounded pebbles in a matrix of sandy clay, sometimes ferruginous. There are some concretionary masses of iron, cemented sandstone, and the gravel is converted in places into a hard conglomerate by infiltrated iron oxides or more rarely by silica. The pebbles are mostly of quartz, frequently rock crystal, but they also include jaspery banded-ironstone, chert, agate, hard sandstone or quartzite, and occasional large and small pieces of silicified wood, as well as fragments of granite and chloritic schist. Large boulders are comparatively rare. The silicified wood, though distributed about in all sorts of positions, may possibly have formed *in situ*, the granite and schist last mentioned are the only other constituents of the deposit that are not well rounded. The presence of the agate, as already mentioned, shews the deposit to be newer than the lavas of the Forest Sandstone series. In one shaft, 25 feet of gravel had been passed through at the time of my visit, without any indications of approaching the base, and more recent work has shewn that my estimate of 40 feet is probably a moderate one for the maximum thickness.

The LOWER SANDY BEDS have obviously derived most of their materials from the underlying granite. They are micaceous throughout, the upper and lower parts South of the Railway being clayey with a bed of clean sand in between. The base shews fragments of decomposed granite, and it is difficult to fix the point where the bed rock really begins.

It is clear that in these sands and gravels we are not dealing with the insignificant accumulations of the present-day river system. This is no less evident from the character and distribution of the deposits than from their position on the crest of what is now the main watershed of the country. Their extent is quite in keeping with a lacustrine origin; on the other hand, they correspond closely with the alluvial deposits of rivers which have eroded their valleys practically to the lowest possible level, and have for long been chiefly occupied in widening them and spreading the materials furnished by the process evenly over their flood plains. The Somabula beds may therefore be set down, provisionally, as due to the action of an important Tertiary River or river system, probably a feeder of the

great lake which must once have filled the adjacent portion of the Zambezi basin, and draining an area chiefly occupied by granite and the Archaean banded ironstone.

The gravels of the Somabula are interesting from their unique lithological character, as far as Rhodesia is concerned, but their chief interest naturally arises from their being the source of various gem stones, particularly the diamond. The diamonds themselves are peculiar, as almost invariably of a green shade in the rough: this is, however, entirely lost in cutting. They occur in very good crystals, principally octahedra, spinel twins of two octahedra, twinned tetrahedra, twinned hexatetrahedra, dodecahedra, etc. Etched triangles are characteristic of the tetrahedral faces. Worn stones are almost entirely absent. The mineralogical associates of the precious stone are not precisely similar to those of the Kimberley diggings or of the more recent Transvaal discoveries, but they nevertheless present a general resemblance to those of the localities named. *Garnets* are often common, but are not of the blood-red Kimberley variety. *Ilmenite* is uncommon. Both *magnetite* and *haematite*, of which grains are numerous, are evidently derived from the Banded Ironstone, while the source of the *zircon* and of the *mica* (muscovite) is equally clearly the granite: these minerals have no necessary connection with the original matrix of the diamond. This is also probably the case with the *beryls* which occur. The typical minerals are (besides the diamond) enstatite staurolite, chrysoberyl, kyanite, and sapphire. *Enstatite* is the commonest of the minerals popularly grouped together under the name of olivine at Kimberley, but that found here is a brownish variety. Staurolite is an abundant constituent of the sorted material from the puddling machines. Some of the grains are fairly clear, and might almost be taken for garnets on account of their red-brown colour. *Chrysoberyl* is quite abundant for so rare a stone. The prevailing variety is yellow, but the opalescent (precious) "*catseye*," and the form known as "*alexandrite*," which is green by day and red by candlelight, also occurs. This mineral would seem to be usually a product of contact metamorphism: at the same time, although it is not strictly analogous in a chemical sense, its similarity of composition and isomorphism with olivine are to be noted. As a gem, the ordinary variety is actually called "chrysolite," one of the names properly applied to olivine. *Kyanite* and *sapphire* are unequivocal contact minerals, so are *rutile* and *tourmaline*, whose occurrence may also be noted. The presence of the first-named is interesting, owing to its softness, which makes its survival rather remarkable. Of the sapphires, both the blue and colourless varieties occur, while true rubies and oriental amethysts are also found, though they are distinctly rare, even for such scarce stones. Another stone whose occurrence may be noted is the so-called "Somabula Blue"; this is harder and heavier than common beryl, and is biaxial with a wide ophiaxial angle, cleavage flakes shewing the bisectrix normal to them. It seems unquestionably, therefore, a variety of *topaz*: when cut it is one of the most beautiful gems imaginable.

With regard to the origin of the gems, the mere richness of the deposit is sufficient to indicate a near source for the diamond, although many of the constituents of the gravel itself have obviously travelled far. Despite theories to the contrary, it seems evident from the evidence obtained in New South Wales, as well as in this country, that what is commonly called "blue ground" is in all cases the original source of the diamond, and the occurrence of enstatite, as well as the presence of garnets, points to the same origin in the case of the Somabula field. I am aware that Professor Gregory, without making an inspection of the ground, has pronounced the opinion that the diamond comes from pegmatite veins, but such an idea is so completely at variance with the local conditions, and with all that we know of diamond occurrences, that it scarcely merits discussion. I have little doubt that it will not be long before the pipe which produced the diamonds is discovered, and that it will present, apart from slight local peculiarities, all the usual features of the South African mines already known.

28—CONTRIBUTIONS TO OUR KNOWLEDGE OF THE STONE AGE OF SOUTH AFRICA.

By J. P. Johnson.

Most of the material described in the following notes was obtained during a recent journey, as the guest of Professor R. B. Young, through Griqualand West. It is of the highest interest, throwing considerable light on the long obscure succession in South Africa, and on the vexed question of the origin of the Eoliths, as well as introducing some types of implements which have not been previously described from the sub-continent.

Primitive Group from Leijfontein, Herbert.

In several places on this farm there are patches of gravel lying at the foot of the dolomite escarpment. This gravel consists of sub-angular fragments of chert and jasper, and is probably derived from patches of very ancient drift that formerly existed on the top of the escarpment.

The chert comes from the dolomite, and is the grey translucent variety of cryptocrystalline silica usually met with in that formation. The opaque jasper is brown inside, but externally has changed to a yellowish-brown, and acquired a high glaze or polish.

While the chert may have been supplied entirely locally, the jasper, on the other hand, has travelled a long way, the nearest source being the Asbestos Hills, some thirty miles to the west.

Mixed with the gravel are quantities of much-worn and highly-glazed jasper Eoliths. A few of these are a little more advanced than the true Eoliths, being made from artificially-produced flakes, but they are a very small minority. Otherwise the group is in every way identical with the typical assemblage met with in the early plateau drifts of southern Britain.

Although attention was drawn to the hacked or rudely chipped stones, which are now termed Eoliths, as far back as 1889, their origin—whether artificial or natural—is still the subject of controversy. While some authorities unreservedly accept them as the work of man, others are equally emphatic in denying their artificial character. The specimens from Leijfontein throw considerable light on this matter, and their testimony, in my opinion, is only capable of one interpretation, namely, that they really are primitive man's first attempts to trim pieces of stone to a useful shape.

The Leijfontein Eoliths and flake-Eoliths may be sub-divided in the same way as Prestwich divided the typical Eoliths, that is, into two sub-groups, * (1) those in which the pieces of stone have been subjected to little modification, and (2) those in which they have been chipped into definite shape.

It would be difficult to recognise the artificial character of the implements of the first sub-group if found alone. Their great abundance, and the haphazard appearance of the chipping immediately suggests that they have been shaped by the blind forces of nature. Both circumstances have been brought forward as evidence

* The "Reutelian" and "Mesvinian" of Rutot.

against their artificial character. Nevertheless Palæolithic and Neolithic implements are sometimes met with in equal quantity, while, if the Eoliths are, as is claimed, man's first artéfacts, one would expect them to be barely distinguishable from Nature's work. Their association with others, in which the trimming, though of the same rude kind, is arranged in definite patterns, is the sole ground upon which they can be accepted.

Even the better-defined implements of the second sub-group are of so primitive a kind that their artificial character is still the subject of controversy. Yet, apart from the inferior quality of the trimming, and the fact that most are fashioned out of naturally broken fragments of stone, they are identical with the commoner accepted flake-tools of the Palæolithic and Neolithic periods.

Two series of the more differentiated Eoliths and flake-Eoliths, and a set of Neolithic implements of the best quality, for comparison, are represented by the accompanying illustrations (Plates 1, 2, and 3).

Plate 1 shews a series of straight concave and convex-edged scrapers. A., B. and C. are true Eoliths, while D., E. and F. are flake-Eoliths. A. and D. are good examples of the concave scrapers. It will be noticed that there is quite a wide difference in the quality of the workmanship of these two. There is a still greater difference between the better of these and the Neolithic example D. I have South African Palæolithic specimens which, in point of workmanship, fill the gap. There is no essential difference between the disputed Eolithic examples and the accepted Neolithic ones. B., C., E. and F. are four commonly recurring varieties of scraper, usually designated by the really descriptive adjectives, circular, rectangular, long and broad. All of these can be matched by Palæolithic and Neolithic examples, while one is still to be counted among the domestic appliances of certain savage peoples. Compare the circular scraper with the Neolithic specimen B. Here, again, I can produce South African Palæolithic specimens, intermediate as regards quality of workmanship. This evolution in delicacy of finish is carried a stage further in some beautiful little examples which I have recently obtained at Riverton, in association with minute scrapers like those from Taaibosch Spruit. They are about one-half the diameter of the Neolithic example.

Plate 2 shews an extremely interesting series of implements. They are very typical of the Eolithic stage of culture, being rarely met with in more advanced assemblages. They are probably all scrapers. A. and B. are double-edged scrapers. It will be noticed that the chipping of the one edge is in the reverse direction to that of the other. C., D., E. and F. are very similar implements, but both edges are chipped on the same side. They are an eloquent testimony to the artificial character of the Eoliths. It is incredible that a long, tapering point like that of F. could be hacked out by blind agencies.

I have above alluded to Prestwich's classification of the Eoliths. His essay in "Controverted Questions of Geology" (1896) is still

the best account of them. It discusses the flint examples originally obtained by Benjamin Harrison from the patches of early drift on the chalk plateau near Ightham in Britain. Besides the two sub-groups of true Eoliths, he included a few, amounting at the time he wrote to 6 % of the total finds—a proportion that must now have dwindled to a mere fraction—that are admitted on all hands. Of these, represented by his figures 38 and 39, and perhaps also 10 and 37, not a single example has been found *in situ* in the plateau gravel. The writer's opinion is that these, which are merely rude examples of Palæolithic forms, and which, if they are all in the same condition as those represented by Figs. 38 and 39 (which the writer has seen) are much fresher than the majority at least of the typical Eolithic forms, should be included with those other implements found on the plateau, of which Prestwich says: "It is true that some specimens found on the plateau are as well worked as any from the valley-drifts [Palæolithic] and how to account for their presence yet presents some difficulty, but that they are not of the same age, I feel nearly certain. Not only is their make different, but their condition, their freshness—if it may be so termed—and their rarity constitute differences so great that, placed side by side, they would never be placed in the same category. That they should be found on the plateau is no more surprising than that unmistakable Neolithic implements are found on the same surface, in company with the plateau gravel [Eolithic] implements." It must be remembered that at the time he wrote there were no sections in the deposit, all the specimens being picked up on the surface. No implements of this third sub-group have been found in the sections which have since been specially made.

PRIMITIVE GROUP FROM MAMBIVLAKTE, HAY.

By the homestead on the farm Mambivlakte, there are three flat-topped quartzite hills, one to the north, the other two to the south, of the road. On the middle one, and probably on the others also, there is a covering of dark-coloured jasper, chert, and ironstone gravel, containing numerous glazed flake-Eoliths, mostly of brown and yellowish-brown jasper, like those from Leijfontein.

PRIMITIVE GROUP AND PALÆOLITHIC TYPES FROM KAMEELFONTEIN, HAY.

On the farm Kameelfontein there is gravelly débris like that at Leijfontein, containing worn, glazed jasper Eoliths and flakes with an Eolithic style and quality of trimming. Of these, however, the latter amount to more than one-half of the total implements, so that the general assemblage is in advance of that of Leijfontein.

Further, rude chipped discs and flat, more or less circular, pieces of stone, with an edge worked along part of the periphery, also occur. These last are worked in the same way as the typical Palæolithic implements, by alternately striking a chip first off one face and then off the other. They are evidently the initial stage in the evolution of that class of implement. Some of the specimens

collected are, in fact, primitive examples of the typical Palæolithic implements, and leave no doubt as to the origin of the latter class of implement.

Lying on the same surface, but in striking contrast to these worn and primitive Palæoliths, were some quite sharp and fresh-looking examples of very advanced form and finish. They are of chert and jasper, and comprise both almond-shaped and axe-head types.

PALÆOLITHIC TYPES FROM BETWEEN SCHMIDT'S DRIFT AND CAMPBELL.

At one place on the road from Schmidt's Drift to Campbell I noticed many of the characteristic large Palæolithic flakes, as well as some unfinished examples of the typical implements associated with boulders embedded in red, loamy sand.

PALÆOLITHIC TYPES AND ADVANCED GROUP FROM THE LANGE BERG.

On the farm Zoutputs in the Lange Berg I came across numbers of unfinished Palæolithic implements of quartzite associated with the characteristic large flakes, among débris on the sides and at the foot of a hill. Together with them I found three rather interesting flake-tools of a very primitive kind, but probably contemporaneous with the other implements.

Between the farms Zoutputs and Spitzkop there is a rock-shelter in the upturned quartzite formation. At the foot of the cliff in which it is situated I found many jasper spalls, also flakes of chert, quartz, and quartzite, as well as some specially interesting flake-tools and an incised fragment of ostrich eggshell.

PALÆOLITHIC TYPES AND ADVANCED GROUP FROM PRIESKA.

The Orange River, on the north bank, opposite the village of Prieska, is bounded by a terrace of sub-angular jasper gravel. This gravel is cemented into a hard conglomerate by sand and lime. It is overlaid by sandstone, consisting of quartz grains, similarly bound together by calcareous matter. I saw many much-worn, characteristic Palæolithic flakes, as well as a typical implement; *in situ*, in the deposit, but was unable to extract them owing to its hardness. I, however, obtained one very nice, though worn, specimen, which had only just been freed by atmospheric disintegration of the matrix. There are many similar jasper Palæoliths, as well as some of quartzite, in the bed of the river, that are evidently derived from this deposit, and of which I brought away some examples.

The presence of the Taaibosch Spruit group among the overlying sand-dunes is indicated by fresh jasper spalls, and by the finding of a characteristically small jasper core, coloured chert flake, and grey chert scraper, as well as a hemispherical stone like that from the junction of the Riet and Modder Rivers, but with the hole barely started.

PALÆOLITHIC TYPES AND ADVANCED GROUP FROM THE JUNCTION OF THE RIET AND MODDER RIVERS.

The above locality has been rendered classical by Rickard's account of his discovery of Palæolithic implements there. His paper, "Notes on Four Series of Palæolithic Implements from South Africa," * is one of the few of any good that have been written on South African stone implements.

"The Implements from the Junction [of the Riet and Modder Rivers] were found in the bed of the river immediately below the point where the rivers become confluent, lying either on the bare rock or in small hollows containing a little coarse gravel; I collected upwards of eighty specimens in a few hours, but had to abandon the majority of them on account of the difficulty and cost of transport."

He devotes two plates to them. Plate I. shews two typical tongue—or almond—shaped implements. Plate II. shews a fine representative of the axe-head type, drawn to actual size.

I, also, obtained quite a number of both types there, but they were all very much water-worn, being practically reduced to pebbles. I have no doubt that they come from the gravelly stratum at the base of the alluvium (= lower terrace of the Vaal). This was east of the bridge.

West of the bridge, and some little distance north of the river, I found a great quantity of quite fresh and sharp scrapers of grey aphanite, mixed with flakes and cores. They had been exposed to view by the removal of a thin covering of surface soil.

Nineteen examples are shewn in the accompanying illustration (Plate 4). I do not propose to say much about them. Although our knowledge of the Stone Age of South Africa has increased with an unprecedented rapidity during the last few years, the time is not yet ripe for generalisation. It is noteworthy that they present an entirely different assemblage to any that has hitherto been found in South Africa. It is important to note that in order to illustrate as many as possible of the forms met with, I have had to give undue representation to exceptions. Moreover, a number being almost as thick as they are broad, with the edge-trimming nearly, if not quite, vertical, are unsuitable for drawings. The three middle specimens of the second row illustrate the dominant form. Interesting are the extremely elongate kinds, and the variety trimmed at both ends.

These implements are unquestionably newer than the alluvium.

Together with these were found three or four chert scrapers, a grooved cylindrical piece of sandstone, a hemispherical stone with a hole bored to a depth of about one and a half centimetres from the flat side, numerous ostrich eggshell fragments, a bead made of same, and the half of a glass bead.

ADVANCED GROUP FROM RIETPAN (NO. 46), BOSHOF.

The group of implements found at this farm is similar to the assemblage from the junction of the Riet and Modder Rivers, the

* J. C. Rickard, Camb. Ant. Soc., V. (1880).

very thick forms, however, being predominant. The implements, too, are made of the same materials, that is, with the exception of one jasper and five small chert specimens, of the peculiar grey aphanite. They are probably all scrapers, and present the same variability at both places. They occur under a thin covering of surface soil.

The accompanying illustration (Plate 5), if combined with that of the examples from the Junction, gives a very good idea of the general facies. The impossibility of accurately drawing the very thick forms has, however, prevented their receiving representation. As regards size, some are a good deal larger than those figured. They are not common, nor are the minute specimens shewn in the middle row of the illustration. I have one very neatly trimmed example (11,109) that measures only 12 x 9 millimetres.

The very long scrapers, and those trimmed at both ends, are well represented. There are also two or three examples of a peculiar wedge-shaped form (which also occurs at Riverton)—they are trimmed all round, the secondary chipping being nearly or quite vertical at the sides and convex end, but inclined at a comparatively low angle at the straight end.

While a large proportion are most exquisitely finished, a great many have been very roughly made. These last are interesting on account of the light they throw on the Eolithic question. Many, indeed, shew little or no improvement on their prototypes.

An ostrich eggshell bead and a piece of pottery were found, together with the implements.

PALÆOLITHIC TYPES AND ADVANCED GROUPS FROM RIVERTON.

Riverton Island is famous for the outlines of animals and the curious symbols which are chipped on the polished rock surfaces. The great eland mentioned by Stow is still in existence, though sadly damaged.

On the south side of the river, both terraces and the alluvium overlying the lower one, are well developed. In the lower terrace I noticed several of the characteristic large flakes, and obtained one or two of the typical Palæolithic implements.

Above the alluvium is a thin covering of constantly shifting sand. In places where this had been blown away, I came across in great abundance a most interesting group of implements. Apart from hammer and grind-stones, a perforated ball, and grooved cylindrical pieces of sandstone, they may be divided into three series:—(1) Scrapers of grey and green aphanite, resembling in a general way those from the junction of the Riet and Modder Rivers, (2) minute scrapers like those recorded by me from the Taaibosch Spruit, (3) Pigmy chert implements of remarkably delicate workmanship, mostly of peculiar form and unknown use.

Thirty-nine of these last are shewn in the accompanying illustration (Plate 6). They are a Neolithic type that is already known from Europe (including Britain) and India, but of which only one example

—the crescent variety—has hitherto been recorded from South Africa. For reasons given in a previous paragraph, I do not propose at present to bring forward any conclusions based on them, preferring, in the present state of our knowledge, to allow them to speak for themselves.

In addition to the above, I obtained fragments of pottery and a number of ostrich eggshell beads, as well as spherical and cylindrical glass beads. These last, though much discoloured, through long exposure to the weather, probably have no connection with the implements, there being all sorts of other modern débris associated with them in places. At the present time there are a number of natives living in huts on part of the old site.

PALÆOLITHIC TYPES AND ADVANCED GROUP FROM THE MOUTH OF THE HART RIVER.

On the left bank of the Hart River, at the drift near its junction with the Vaal, numerous shafts have been sunk down to, and tunnels driven along, the diamond-bearing layer at the base of the upper terrace. The deposit consists of well-rounded boulders in a matrix of much rolled river gravel. I saw many of the large, characteristic Palæolithic flakes among the heaps of excavated stones. They were in the same water-worn condition as the rest of the constituents of the deposit. On one heap I also picked up two of the typical Palæolithic implements, but these are not so much worn and may possibly not belong to the deposit.

Just west of the mouth of the Hart River, I obtained a typical Palæolithic implement, and saw many of the large, characteristic flakes *in situ*, in the lower terrace, which here consists of a thin stratum of gravelly detritus lying at the foot of a cliff of tufaceous limestone, and overlaid partly by alluvium, and partly by a talus of the tufa.

On top of the cliff, and some little distance back from the river, I obtained a large number of minute scrapers, mostly of coloured chert, similar to those from Taaibosch Spruit, some very nice "pigmies," like those from Riverton, several ostrich eggshell beads, a circular stone with flat sides and edge, a cylindrical glass bead, and some pieces of pottery.

ADVANCED GROUP FROM ROCKSHELTERS IN THE ASBESTOS HILLS.

During my recent trek through Griqualand West, I crossed the Asbestos Hills twice, on the outward journey by Kranzfontein, and on the return by Griquatown. At both points I noticed many rock-shelters, all of which were no doubt inhabited at one time or other. In all that I examined, quite fresh and sharp spalls of the local jasper were abundant, while a careful search brought to light a number of minute flake tools, fragments of pottery, and ostrich eggshell beads.

On the farm Kranzfontein the rockshelters occurred in the precipitous sides of a winding kloof. I examined two of them.

Some of the objects obtained are shewn in the accompanying illustration (Plate 8). Those in the two left-hand rows are from one rockshelter, the rest are from the other. They are mostly scrapers, made chiefly of the local jasper, but also of grey chert from the dolomite and coloured cherts, and agate from the Vaal River amygdaloids. The remarkably small core, from which correspondingly minute, long, narrow flakes have been struck, is a particularly eloquent testimony to the skill of the makers of these stone implements. Very interesting, too, is the sea-shell, of which two views are given, the incised ostrich eggshell fragment, and the ostrich eggshell bead. I also obtained a couple of facetted grinding-stones, one from each shelter.

From among débris on a hill close by I also obtained a typical Palæolithic implement of jasper. It has rather an old appearance, and does not suggest any connection with the rockshelter implements.

The kloofs at Griquatown are full of rockshelters. Stow mentions aboriginal paintings in one of them, but there were none in those I examined. I obtained quite a nice series of flake-tools of jasper and chert in them. Twenty-two examples are shewn in the accompanying illustrations (Plate 7). Some of them are very fine instances of work in stone, but the drawings, unfortunately, do them scant justice.

Though there is a difference in detail between the groups figured from Kranzfontein and those from Griquatown, the general facies is unmistakably the same. The assemblage is very similar, though by no means identical, with that of Riverton. The very long scrapers and those trimmed at both ends are represented, as also are the "pigmies" by some very neat specimens.

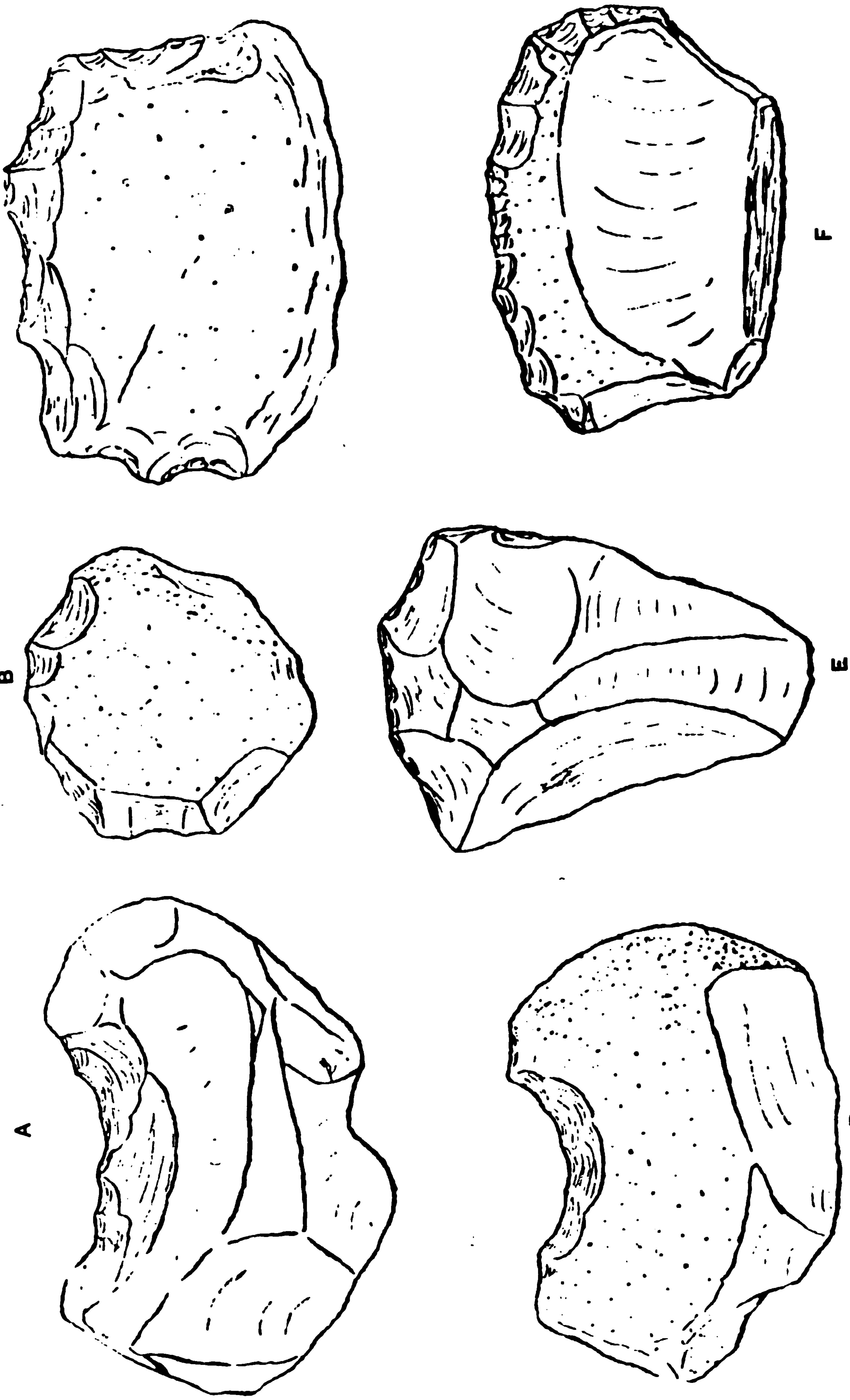
There must be a wealth of interesting material hidden away in these rockshelters. The specimens I obtained are the result of a hurried examination during a two or three hours' outspan, and can be but a tithe of what would reward a systematic exploration.

ADVANCED GROUP FROM BLAUWBANK (O. 376 D.), HAY.

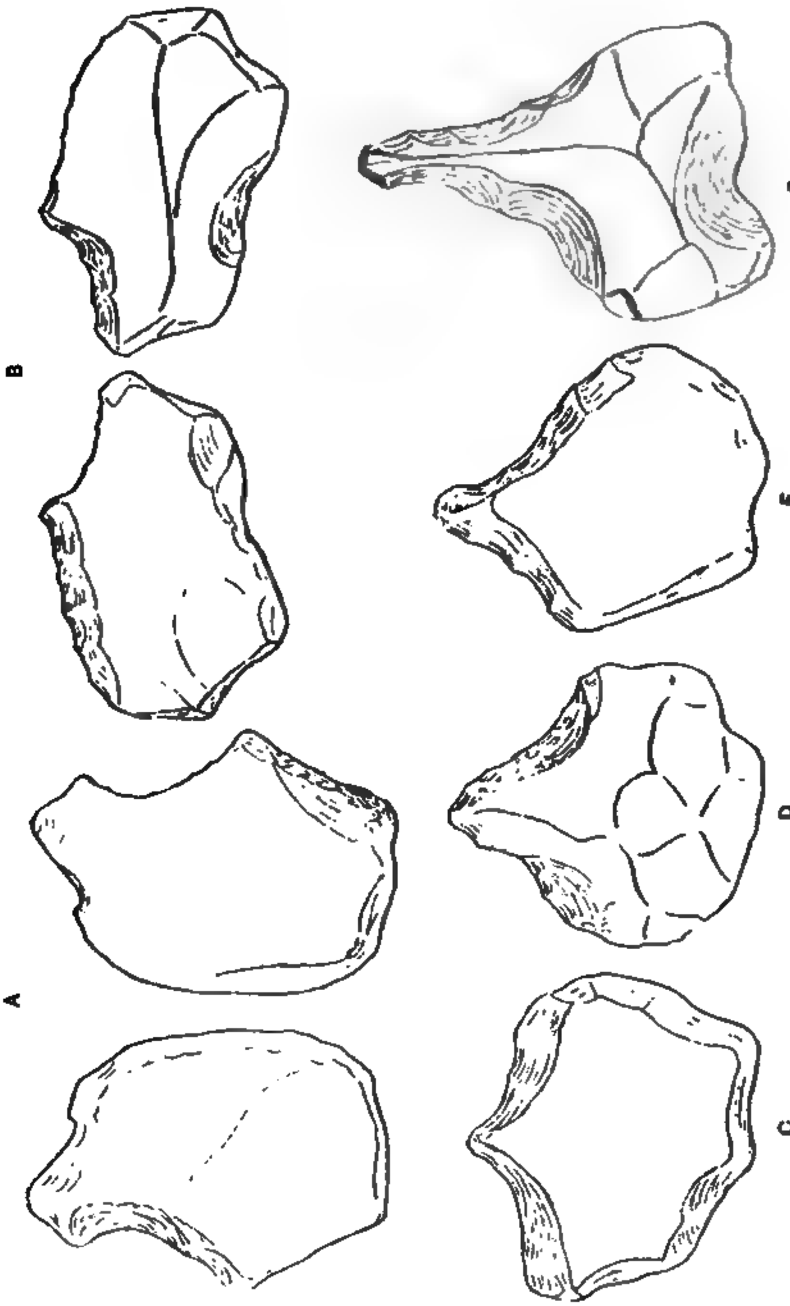
On this farm, which is situated on the banks of the Orange River, I obtained a nice series of minute chert scrapers like those from Taaibosch Spruit, as well as some neat "pigmies," among sand-dunes. Together with them I found fragments of pottery, two small glass beads, and numerous ostrich eggshell beads. These last occurred in every stage of manufacture, from a piece of shell with the hole just started, to the finished article. Many had been broken before completion.

ADVANCED GROUP FROM LYMPUTS, HAY.

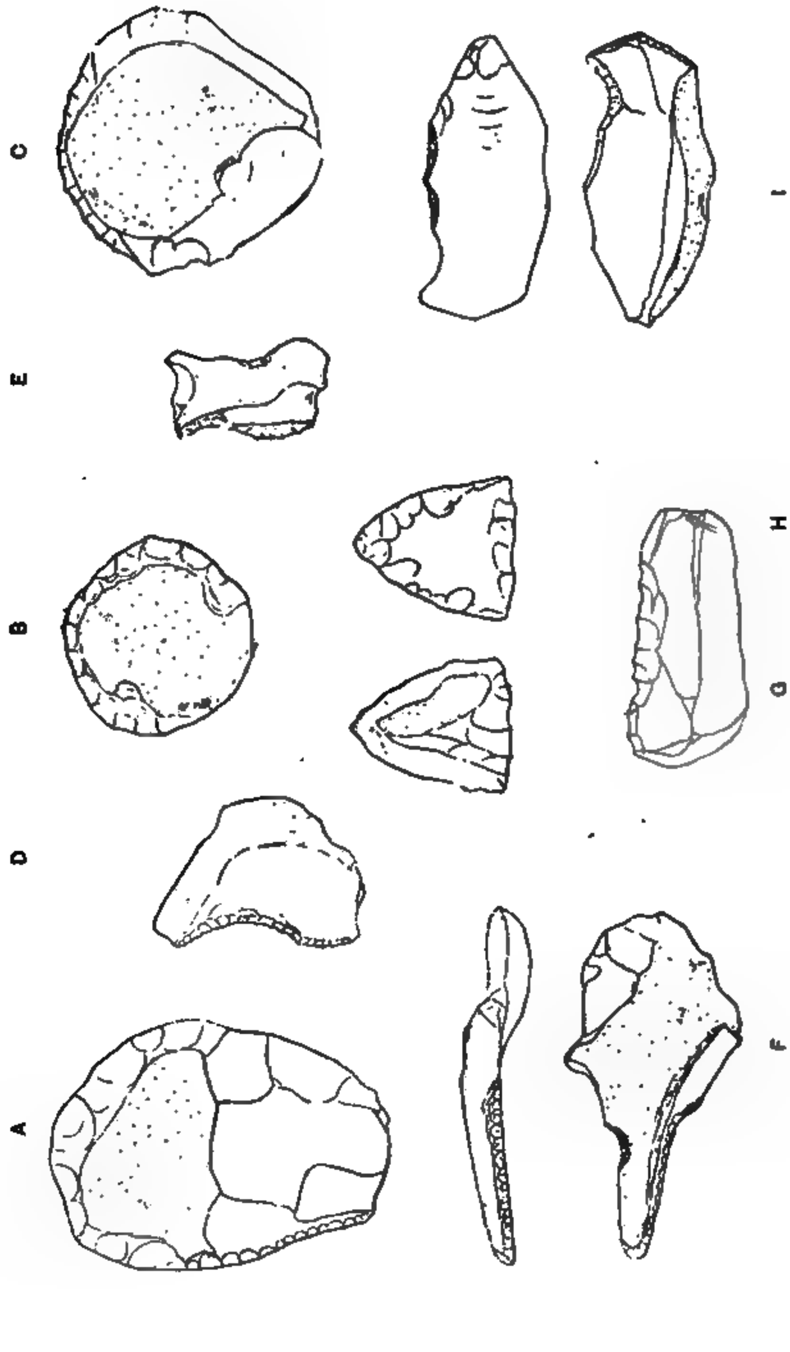
On the farm Lymputs I obtained a number of minute jasper scrapers of the Taaibosch Spruit type, associated with flakes of green aphanite, among low kopjes bordering a spruit.



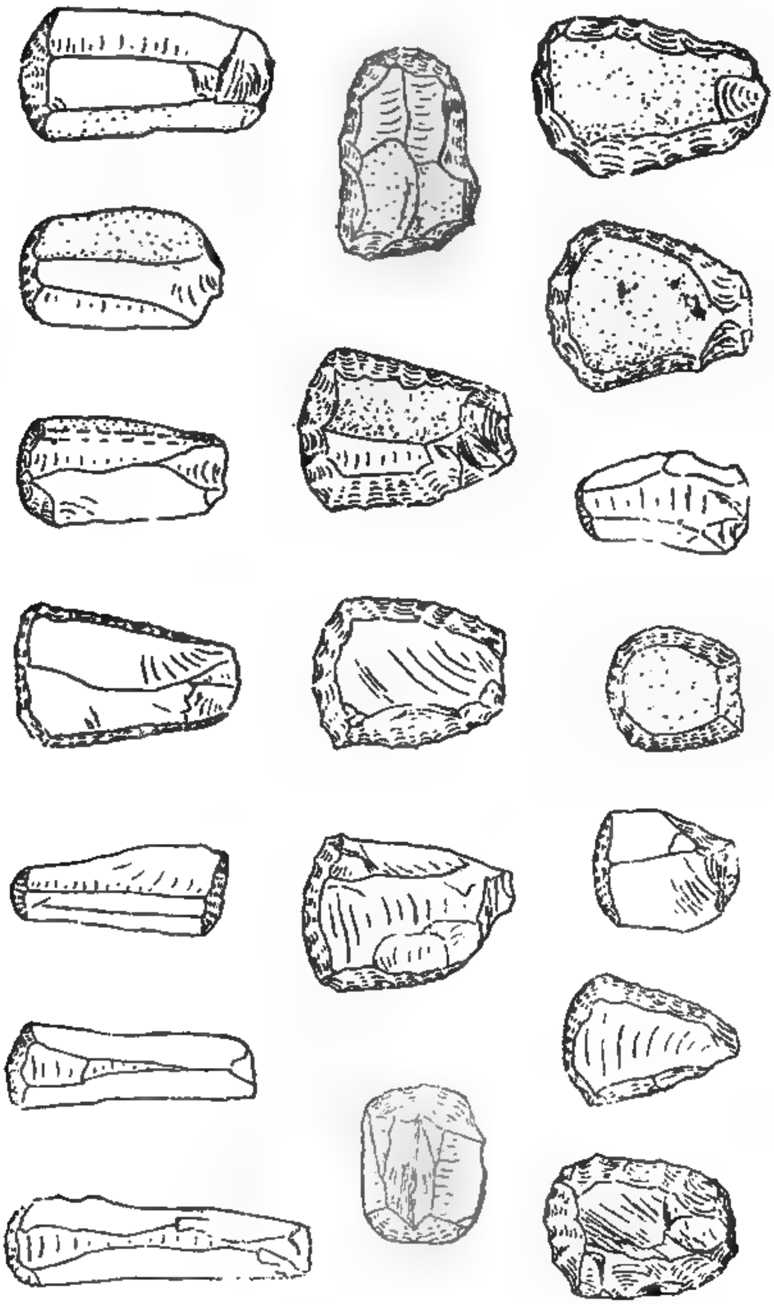
I. PRIMITIVE GROUP FROM LEIJFONTEIN, HERBERT.



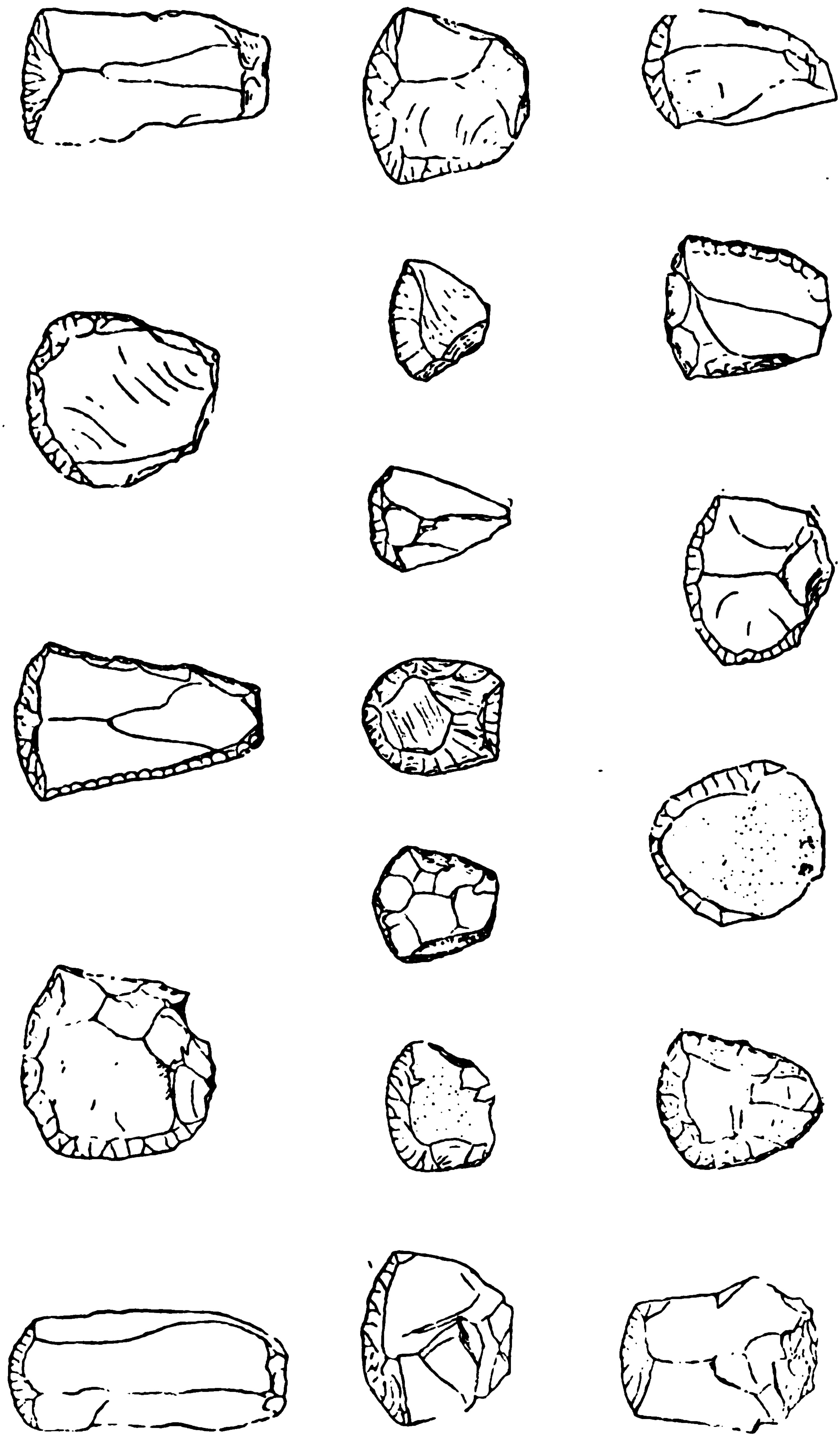
2. PRIMITIVE GROUP FROM LEIJFONTEIN, HERBERT.



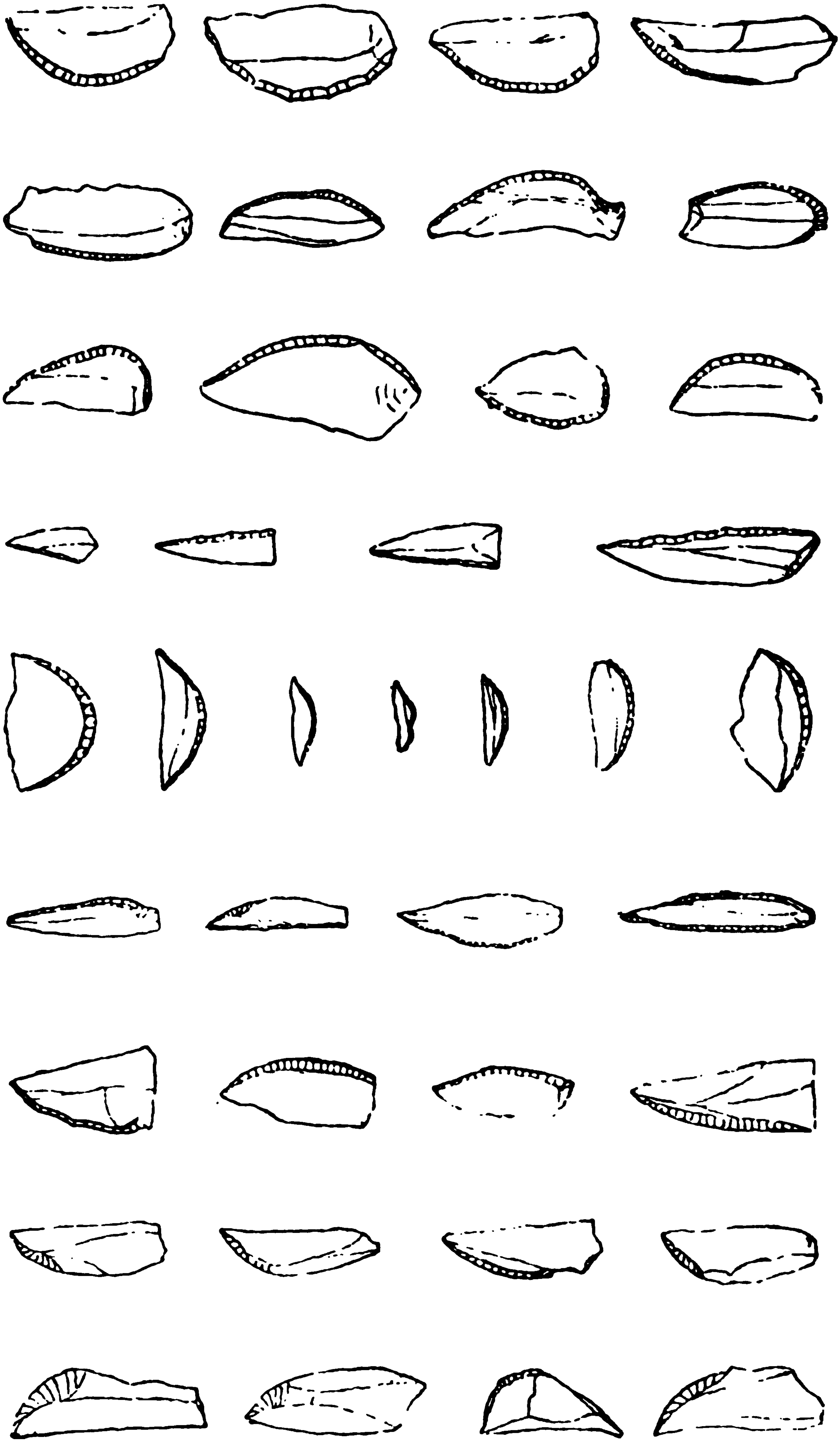
3. Neolithic Group, Sutton (Britain).



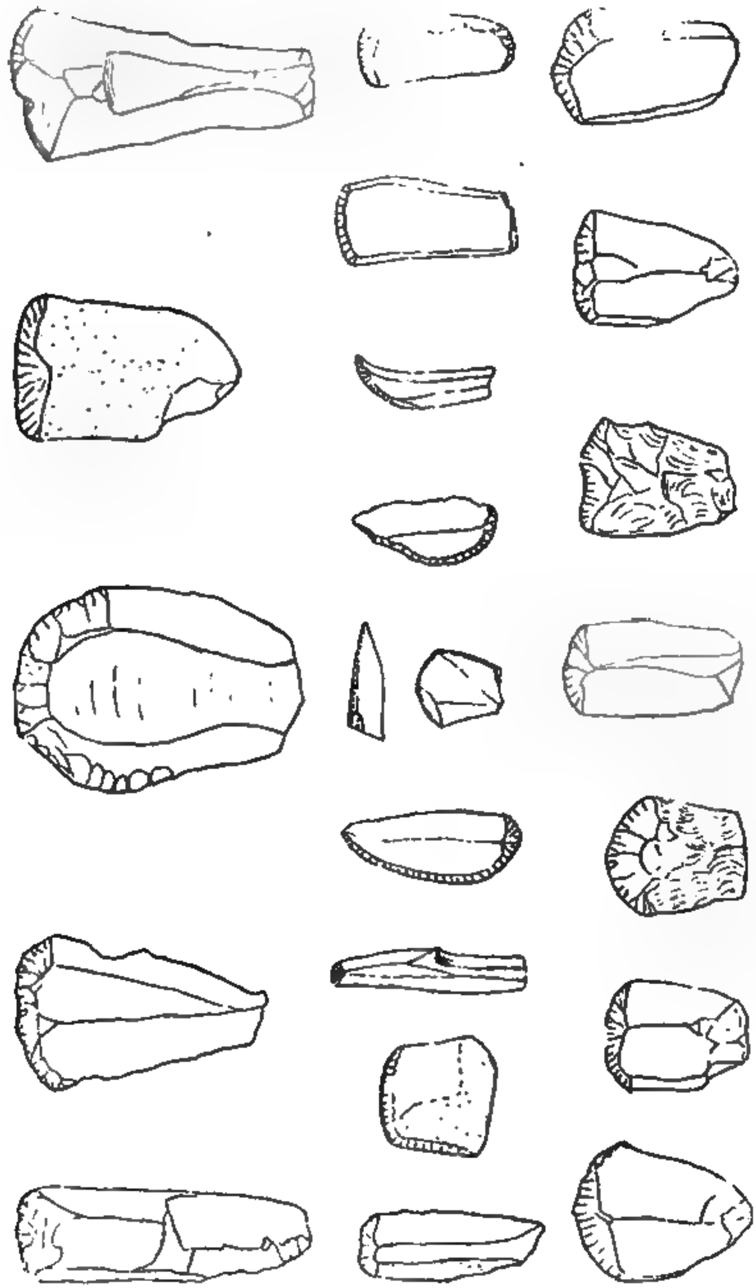
4. ADVANCED GROUP FROM JUNCTION OF THE RIET AND MODDER RIVERS.



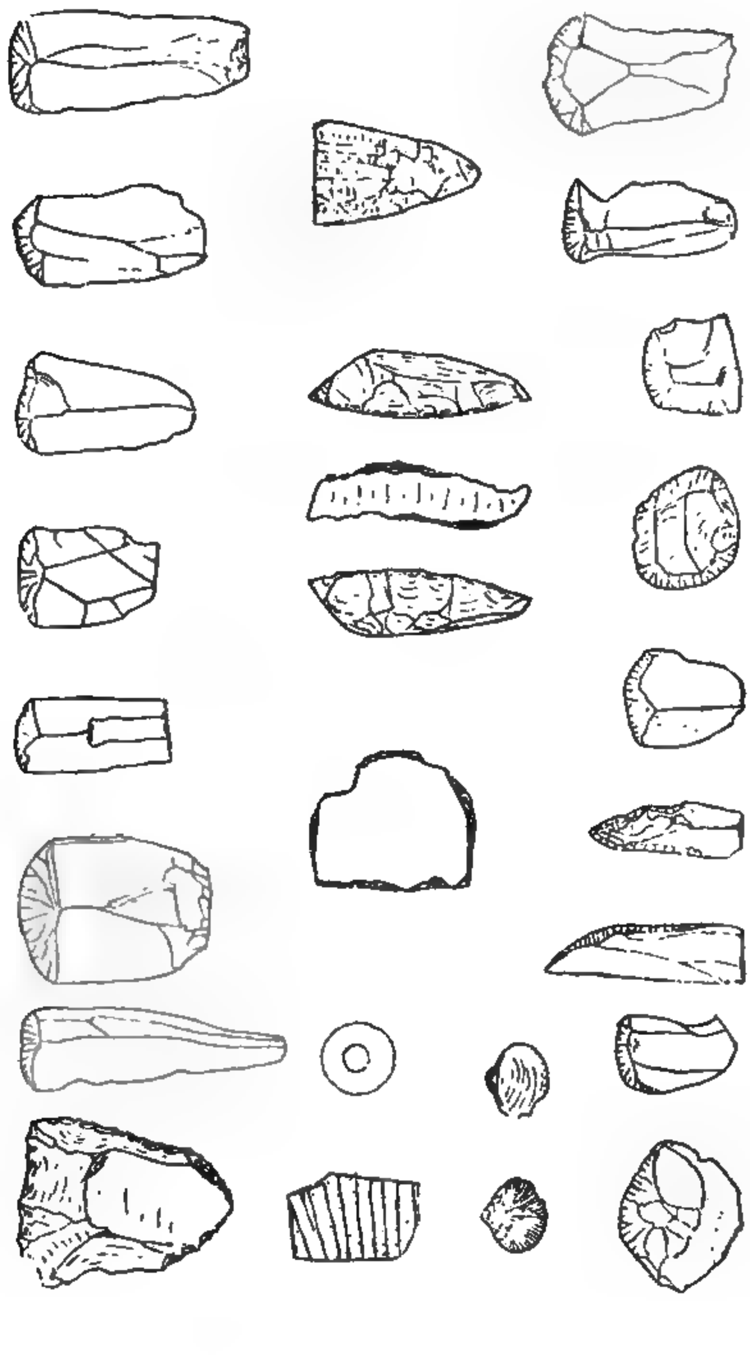
5. ADVANCED GROUP FROM RIETPAN, BOSHOF.



6. PIGMY IMPLEMENTS FROM RIVERTON.



7. ADVANCED GROUP FROM GRIQUATOWN ROCKSHELTERS, ASBESTOS HILLS.



8. ADVANCED GROUP FROM KRANZFONTEIN ROCKSHELTERS, ASBESTOS HILLS.

29—THE BLACK RUST OF WHEAT.

By J. B. Pole Evans, B.Sc.

[Paper not Printed.]

30—INFECTIOUS EXPERIMENTS WITH UREDO GRAMINIS, PERS.

By J. B. Pole Evans, B.Sc.

[Paper not Printed.]

31—IMMUNITY OF CERTAIN WHEATS TO RUST.

By J. B. Pole Evans, B.Sc.

[Paper not Printed.]

32—SYSTEMATIC DESCRIPTION OF THE TRANSVAAL PLANTS OF THE FAMILY OF AMARYLLIDACEÆ.

By Miss R. Leendertz.

Curator of the Transvaal Museum Herbarium.

[Paper Not Printed.]

SECTION C.

Agriculture, Architecture, Engineering, Geodesy. Surveying and Sanitary Science.

Section C.

PRESIDENT'S ADDRESS.

33—WASTES IN MINING.

By Sidney J. Jennings, C.E., M.Am.I.M.E., M.I.M.M.

I have been guided in my choice of a theme for the opening address of Section " C " of the Association, by the desire to find some subject in the Mining Engineering profession which would be of interest, not only to the members of that profession, but also to the followers of the many other branches of scientific enquiry gathered together under that Section.

If there is one subject more than another that is of universal interest to the men who make applied science their life-work, that subject is Waste. A celebrated French Chemist is credited with the saying that he would take for his share of the world's goods what other men threw away. The spirit underlying this remark, a spirit of unceasing investigation into waste products, of continual production of something valuable from substances previously thrown away, has made possible in no small degree the material prosperity and comfort we enjoy in the present stage of civilization. But it seems to me that there are other kinds of waste, even more important, than that of products, and I would like you to consider with me some of these wastes.

The subject is a very vast one, and I will not pretend to do more than indicate a few heads under which it may be considered. Each one of us can elaborate these heads for himself, and supply illustrations out of his own experience. For my purpose this morning, it will be sufficient to consider briefly the three different kinds of wastes in mining that go to increase the failures in that branch of business. These three kinds of wastes are :—

First, the waste of thought.
Second, the waste of labour.
Third, the waste of material.

I have placed them in this order, because it seems to me the order of their importance, measured by their effects, and also because it is the order of the difficulty of recognizing their presence. It is comparatively easy to perceive the waste of material. The wasted product does not vanish, but lies there, accusing its creator of ineptitude; it, however, always offers a chance of some use in the future being found for it. The waste of labour can be seen and checked while it takes place, but once having been wasted, it offers no opportunity of being utilized for any other purpose.

I.—THE WASTE OF THOUGHT.

It is difficult to follow the waste of thought into its inmost recesses, but a moment's consideration shows how far-reaching such waste is. I do not mean by waste of thought errors of judgment. These last erect for themselves monuments visible to all the world. I mean by waste of thought that habit of mind which tries to shut itself up from the influence of others and laboriously restates a problem and then equally laboriously attempts to solve it, when a little more knowledge would have enabled the worker to find the problem satisfactorily solved by some one else without any waste of thought on his part.

Modern Mining, in which comparatively so few of the methods have crystallized into hard and fast lines, offers a particularly good field for illustrations of this kind of waste. Definitions of a mine have varied all the way from that of the disappointed speculator, who declared that a mine was a hole in the ground owned by a liar, to that of the geologist who stated that a mine was an excavation in the earth so designed as to permit of the extraction of minerals. For our purposes we must add the business man's conception of mining to that of the geologist, and introduce the idea that mining is a commercial pursuit designed to yield a profit on the working. This conception of mining cannot be too much emphasized, for it is precisely in order to achieve this point of making mining profitable that wastes of all kinds must be eliminated.

I know very well that this commercial aspect of the question is not the only, nor is it the greatest, attraction of mining. There is a glamour about the pursuit, especially the mining for precious metals and precious stones, which lures men on, when their business instinct tells them that they have gone far enough, but the commercial aspect of mining is the solid foundation which permits of this business being carried on, and continually expanded, and this aspect should therefore be greatly emphasized.

When men began to analyse the process of mining minerals from the earth, the great cost of preparing the excavations necessary for the purpose probably first impressed them. Some means were sought by which this cost could be reduced. Very soon there probably arose some man with the suggestion to do away with the excavations altogether; his argument probably being that the only necessity for large excavations was to enable men to get to the places where the ore was; that it would be much simpler to get some solvent that would selectively dissolve the desired material from the surrounding waste, and the enriched solution could be pumped to the surface and there treated so as to separate the solvent from the dissolved commodity sought for. This idea proves wonderfully attractive to some men; all the more so because in certain cases it has been successful. Many salt mines are worked on this principle; some copper mines under very special circumstances have used this idea, the solvent in these cases being water. I have also heard of one silver mine worked on this scheme, the solvent being hyposulphite of soda.

Since the discovery of the solvent action of cyanide of potassium on gold, it was to be expected by anyone possessing any knowledge of human nature that the idea of treating gold ores, *in situ*, by cyanide of potassium would be suggested. But I must confess that I have been surprised by the number of times this idea has been brought to me, and the different classes of men who have suggested it. The care and thought devoted to the perfection of the details of the schemes have been very great, while their essential difficulties have been forgotten in the enthusiasm, fired by what their inventors conceived to be a new and great idea.

While I am the last who would defend an idea merely because it is old, or who would seek to prevent the enquiry by new minds into old and apparently well-established practice, I think that you will agree with me in including all the energy expended on the above outlined idea in the category of wasted thought.

In the sphere of exploitation of mineral deposits, no better illustration of my meaning can be had than the above. Other instances in the same realm will occur to all of you, which set forth in a smaller way what the enthusiast above referred to illustrates on a large scale. These I will not touch on, but there is a set of instances which applies to another side of the mining industry which equally well illustrates my meaning. I refer to the problem of administration of the mining industry.

It has been well said that the best form of Government is that of an Omniscient Despot. But as we can in this world only get a despot without omniscience, we have been constrained to try some other form of Government. Nevertheless, men have always a hankering after the best, and, consequently, whenever a man arises who shows, even in some degree, an all-embracing knowledge, other men, all willing to work for the one-man show, come under his banner.

Situated as most metalliferous mines are, far away from the stir of cities and the crowding of men, the administration of a mine tends to become that of a one-man show. This undoubtedly accentuates the individuality of the Manager, makes him self-reliant and resourceful, but it also tends by that very accentuation of individuality, to make him insist on doing things in his own way, without sufficient consideration whether that way is the best one possible. The very resourcefulness of a Mine Manager induces him to try all sorts of experiments which others have tried and tried again, and whose futility has been thoroughly demonstrated. These defects of the virtues of a Mine Manager are not so prominent when there is only one mine in a camp, but when, as in Johannesburg, you have over sixty producing mines, the subtle friction of mind upon mind produces all unconsciously to the individual an excitation which is apt to result in a series of experiments, the vast majority of which will have been tried before, and the resulting waste of thought will be great. Some years ago a Mine Manager boasted to me that he had never been over any other mine on the Rand except his own. His plant showed evidences of this. Some things were excellent, but many designs showed evidences of great ingenuity in doing things in a roundabout way, the

same effect being accomplished on neighbouring properties in a very much simpler fashion.

One of the means adopted on the Rand to obviate this waste of thought has been the grouping of several mines under one Central Administration. While undoubtedly centralization, when pushed to an extreme, can have a deleterious effect in crushing out initiative and reducing the sense of responsibility of the Manager, it has had, and when wisely administered will continue to have, a most beneficial effect in making the results of one experiment in any given direction, whether positive or negative, immediately available to all the members of the group, by aiding the Manager in all his difficulties with the advice of another experienced and matured mind, thus substituting the deliberative judgment of two men for the possible rash acts of one. Centralization also allows the results achieved in any one department of a mine to be compared on a uniform basis with the results achieved in the same department on any other mine of the same group. Thus while centralization saves the waste of thought in experimenting and resolving problems already adequately disposed of, it promotes thought in showing what other men have achieved in the same line, for nothing gives cause for such quick and steady thinking as a comparison on a uniform basis which shows your own work in an unfavourable light. Centralized management has also other advantages which do not come within the range of our present consideration, and which therefore I will not deal with now.

Undoubtedly it can be pushed to such an extreme that its evils outweigh its advantages. But these prejudicial effects are not inherent in the idea of centralization; they are mere excrescences which have been allowed to grow on the system, whereas the good that can be achieved by the system is an integral part of the idea on which it is founded. These inherent advantages give the centralized system a vitality by means of which it must survive any surgical operation, however heroic it may be, necessary to cut away its abuses.

II.—THE WASTE OF LABOUR.

The waste of labour is so easy and so universal in comparatively new industrial enterprises that it is somewhat difficult to give really striking examples that either startle by their magnitude or arrest the imagination by their novelty. The muscular energy with which any one man is endowed is a certain strictly limited amount; but by the exercise of his brains and the use of tools this energy may be multiplied by many thousand. Wherever man is utilized purely as a source of muscular energy, there you will have to look for and you undoubtedly will find, waste of labour. Here in South Africa, where the division between labourer and overseer is so sharply accentuated by the colour line, where the Kaffir forms such an exceptionally powerful muscular machine and at the same time is supposed to be so relatively cheap, the temptation to waste labour is tremendous, and is I am afraid not always successfully combated. Not only does

this waste of labour comprise the relatively cheap Kaffir, but extends to the much more highly-paid overseer; for if labourers are employed in too great numbers on any given piece of work, the cost of supervision must in proportion be unduly inflated. Viewed as a source of human energy the Kaffir stands high in the scale of labouring people, but from the facts that relative to his wants his remuneration is enormous and that his sense of responsibility is very inadequately aroused it is difficult to train him to be as efficient a workman as he is seemingly capable of becoming.

There exists but little doubt that if the Kaffir were forced by the promptings of his own unsatisfied wants to work continuously year in and year out, that he would become an excellent labourer. But owing to the fact that his wants when he is in his native kraal are limited, and that he is in reality a landed proprietor, he is able to accumulate in comparatively few years sufficient wealth to live in what appeals to him as being the most agreeable fashion for the rest of his life. That is, he works hard for two short spells in the year, at the planting and reaping seasons, in order to cultivate enough land, the produce of which together with the yield of his flocks will suffice to feed himself and his family.

The wages that the Kaffir has, through his mastery of the labour position, forced the industrial to pay him, enables him to earn this comparative wealth by working on the average not more than half the year for a very few number of years. This means that the men engaged in directing industrial enterprises have to put up with a constantly fluctuating labour force, and the proportion of entirely untrained labourers is unduly large. Either one of these factors would tend largely to a wasteful use of labour; their combination results in a state of things which, in spite of the constant and unremitting care of the managers of all large industrial enterprises, is neither satisfactory to them or beneficial to the Kaffir.

As a striking example of the waste of labour that takes place in pursuits other than mining, I may be allowed to quote the following figures. According to the 12th Census of the United States, out of a population of 76,303,387 people, 9,349,922 males were engaged in agricultural pursuits. Thus for every male engaged in agriculture, not only were 8.2 people fed, but an enormous quantity of food products were exported, and sufficient raw materials, such as cotton, wool, hides, timber—grown not only for its own manufactures, but leaving an extremely large surplus for export.

From the latest figures available to me of the Cape Colony, which comprise the only complete returns I have seen, I find that out of a population of 1,652,036 people, 323,601 males were engaged in agriculture. Or for every male engaged in agriculture only 5.1 people were partly fed, as Cape Colony is a large importer of food products, and not only was the export of raw materials, such as wool, hides and feathers small, but the amount consumed in manufactures in those Colonies was practically nil.

While it is impracticable to accurately compare the above figures, they present a sufficiently startling point of view to make one realize

the enormous waste of labour occurring in agricultural pursuits in this Colony.

As far as the routine surface work on the mines of the Witwatersrand is concerned, their managers claim, and, I think, with justice, that the waste of labour has been reduced enormously since the opening of these fields, and that the margin for further reduction in this direction is very small. As an example of what has been done, I would instance the fact that the number of employees in a certain 100 stamp mill with crushers, in the year 1890 was 28 white men and 121 natives; this mill crushed under 5000 tons a month. At the present time a 100 stamp mill crushing 14,000 tons of ore a month will only employ 11 white men and 27 natives; showing that the labour, measured by the tons crushed, has been made 11 times as effective.

I have seen, as doubtless many of you have also seen, a Kaffir who looked on a shovel for the first time, and whose conception of its use was limited to placing it on the ground, carefully filling it with ground scooped up in his hands, triumphantly placing it on the top of his head, then bearing it off to the spot to which the ground was to be shifted. And I have also seen Kaffirs who were able in a day to load 40 tons of sand into trucks, and shift them 40 feet—a task which would be considered excellent work anywhere in the world. If the labour force of any industrial venture is largely composed of men like the first-mentioned, a huge waste of labour will for a time be the result, whereas if any very large proportion can accomplish similar work to that of the second set of workers, then the manager of such an enterprise can view an inspection of his labour sheets with equanimity and unconcern.

While undoubtedly an enormous amount has been accomplished in reducing the waste of labour on the mines of the Witwatersrand, we still have to acknowledge that enough remains to be done to engage the serious attention of those who have the interest of these mines at heart. Personally, I am no great believer in what has been called "dramatic economy of labour." Under such an impulse, the interest on the capital necessary to be spent in order to save the labour of one man, is apt to exceed the wages which would have to be paid that man. I am, however, a great believer in the slow, laborious, but permanent effect of education on the labourer. Catch the Kaffir young, educate him so that he knows how to work, instil into him sufficient ambition and enough wants to make it necessary for him to work continuously in order to satisfy them, then that very necessity for continuous labour will draw out and increase his sense of responsibility, so that he can be trusted to do his work properly without the excessive and wasteful supervision now necessary. Also educate the overseer to realise that he is a foreman of a gang of labourers whom he has to train to work to the best advantage, and this accomplished, you will have probably reduced the waste of labour to the minimum possible under South African conditions.

III.—THE WASTE OF MATERIAL.

In considering the third kind of waste in mining, that of material, the subject divided itself naturally into two sub-heads:—

1st.—The waste of the mineral sought for.

2nd.—The waste of materials used in the process of acquiring the mineral.

On the Witwatersrand enormous strides have been made in reducing the first-named waste. In 1891, on one of the better managed Companies of those fields, a close inspection of the gold returns showed that only 57 per cent. of the assay value of the ore was recovered. In other words, for every sovereign's worth of gold contained in the ore treated, only 11 shillings and fivepence worth were recovered; whereas under the latest metallurgical practice on those fields by the use of tube mills, 95 per cent. of the assay value of the ore has been banked. This means that out of every sovereign's worth of gold contained in the ore treated, 19 shillings were put into the Bank.

Of course, the difference between 11/5 and 20/- was not all lost. A large portion of this difference was contained in the tailings which were stored and treated in subsequent years. None the less, an immense advance in metallurgical practice has been made; so great indeed has this advance been, that on the best equipped mines little remains to be done in the direction of reducing waste of the commodity sought for. The ingenuity of the engineer is exercised in bringing older plants into line with the newest practice at the least cost for capital expenditure.

The waste of stores used on the Gold Mines of the Transvaal has been great in the past and continues at an excessive figure. This is a case where the directing brain is practically at the mercy of the performing hands. Large reductions have been made in the cost of coal, explosives, cyanide and candles, which form the four largest items of expenditure of the gold mines. In the case of coal, this reduction has been achieved by decreasing the railway rates, and also by a slight reduction in the price at the pit's mouth. The cost of dynamite has been reduced nearly one-half through the freeing of the country from the grip of the former monopoly. Through improvements in manufacture, and by the competition of manufacturers, the cost of both cyanide and candles per unit consumed has been greatly reduced. As far as coal and cyanide are concerned, a close supervision of their consumption has taken place and continues to occupy much of the energies of the engineering and metallurgical talent on the Witwatersrand. I estimate that if all the plants could be run with as small a consumption of coal per ton of ore crushed as the most economical plant uses, then the consumption of coal would be reduced by about one-third of the present amount. While it is quite out of the question, owing to the heterogeneous design of

many of the plants, to expect any such saving to be made, a great improvement can still take place and undoubtedly will gradually be brought about.

The Directors of the Mining Industry have made a long, determined, and serious effort to diminish the waste of explosives, candles, and other stores used underground by paying the men by the results obtained. Some improvement has taken place, but to many observers it seems that an even greater improvement would ensue, provided the intelligent and loyal co-operation of all the men were continuously secured.

I have merely touched the fringe of this very big subject. I have indicated the main heads under which waste occurs, and have suggested certain remedies which I will recapitulate.

Nothing has proved itself so efficacious for the prevention of waste of thought as the free interchange of ideas; made possible by the numerous societies and associations formed for that purpose, among which this Association holds an honoured place. The more vigorous these Societies become, the more closely their proceedings are followed by the members, the more diligent these latter are in research, in like degree will the chances of colossal mistakes and waste of brain energy be diminished. I have also shown what a valuable function in preventing thought waste, centralized management can be made to perform.

I have shown that the fundamental difficulty in preventing waste of labour lies in the untrained condition of the Kaffir for manual work, and the inaptness of many of the white overseers for transforming a semi-savage population into an industrial one. I have also shown that the Kaffir can be inured to labour, and will develop into a first-class source of muscular power when properly treated. I have likewise registered my belief that the most effectual and permanent means of improving away any waste of labour is by educating the overseer to properly fill his position as foreman of a large gang of labourers, and by teaching the Kaffir, through the sharp insistence of varied wants, the necessity and advantage of continuous labour.

The best remedy for the prevention of waste of stores has been shown to be the continued thought of the management combined with the loyal and interested co-operation of the men.

Even if you do not agree with the conclusions I have indicated, I trust you will give this subject your serious thought, for I am convinced that the increased wealth and prosperity of South Africa depend in some large degree on reducing to the minimum possible Wastes in Mining.

34—THE REALM OF ALFALFA.

By S. Hodder, F.R.C.T.

It may perhaps afford some guarantee that more than a mere cursory attention has been devoted to the subject of these notes, if I am permitted to explain that for more than thirteen years I was intimately associated with the development of agriculture in Minnesota and Argentina; moreover, it was mainly due to experience gained in the former country that I was entrusted with the organising of the first authorised system of cereal inspection, and the introducing of the most approved methods and appliances for transporting the cereal crops of the River Plate. These facts are only mentioned here to show that any views hereafter submitted, whether right or wrong, are based on experience acquired under conditions not unfavourable to obtaining trustworthy information and forming careful judgments.

The great question to be determined in the development of the agricultural resources of new countries, lies in the judicious selection of crops to meet the special circumstances of the environment; and in modern times it has been generally recognised that where open prairies constitute the dominant feature in the topography of the country, the winning over of the soil from a state of wildness can be best and most profitably achieved by the cultivation of cereals on a large scale. There is no country in the world perhaps possessing so vast an area of rich lands of this description as the Argentine Republic. Of the three provinces of Buenos Aires, Córdoba, and Santa Fé, comprising in the aggregate an area of 234,000 square miles, or 150,000,000 English acres, more than half of each of the former, and almost the entire province of Santa Fé, present a surface so uniformly level that Darwin records his impressions of this phenomenon in the statement, "Scarcely anything which travellers have written about its extreme flatness can be considered as exaggeration." This particular region is popularly known as the "Great Pampa" of South America, and at the commencement of this year presented the unparalleled feature of having 4,389,100 acres in which alfalfa was growing, unassisted by irrigation, stamping the country with the eminent purpose which Nature undoubtedly intended her to fulfil. Besides these three provinces, Argentina embraces a further area of 800,000 square miles, divided into twenty provinces and territories, which are for the most part mountainous, and enjoy a diversity of climates and geological formations.

For the purpose of illustrating from an economic as well as a practical point of view, how inseparably the growing of cereals and alfalfa are linked together, it is necessary here to make a slight digression, and as we proceed the vital importance of this combination will appear with increasing distinctness. In the early eighties, when the prairies of the Red River Valley and the Great North West came under notice as cereal-producing areas, farms of 5,000 acres sown with wheat were by no means uncommon. The "Dalrymple Farm" at Fargo, boasted of as being the largest wheat farm in the world, had under cultivation about 56,000 acres. A decade later the pampas of Argentina furnished numerous examples of even still

larger tracts constituting a single wheat field; a reference to one of these will serve as a sample of the rest. In the year 1891 Mr. José Guazzone, of Azul, offered to sell on the Bolsa at Buenos Aires the produce of 80,000 acres which comprised his wheat farm.

But sooner or later a day will come to these regions when cereal growing can no longer be practised on the same gigantic scale: the huge farms that form epics in agricultural industry must cease, and the exhausted soil must be given an opportunity to regain its lost fertility. This means that a new stage of development becomes imperative, and extensive farming, in the broadest interpretation of the word, must give place to high farming on extensive lines, with all the problems associated with the selection of cultivated grasses and artificial fertilizers. In the United States and Canada agricultural investigators of the first rank are busying themselves to solve this intricate problem, which in those countries bristles with difficulties: meanwhile, by adopting a system of alternately cropping and summer-fallowing it is sought to prolong the wheat-yielding capabilities of the soil. On the other hand, in Argentina the farmer is confronted with no difficulty whatever; right away he steps from the first stage of development to the climax, without curtailing his income by the smallest fraction, and there is no pause during the transition. The explanation is to be found in the circumstance that alfalfa, the greatest forage plant, and the greatest soil renovator the world has even known, flourishes with the maximum of luxuriance on every farm in the country that has previously produced cereals.

At the present time the area laid down under alfalfa exceeds 6,500,000 acres, many individual farmers possessing more than 15,000 acres sown with the plant. The full significance of these vast expanses, carpeted with bright green herbage of the highest nutritive value, baffles the comprehension of the ordinary observer; it can, however, be accurately gauged by a perusal of the statistical abstracts periodically published by the Minister for Agriculture, who has described alfalfa as "the backbone of the country's prosperity." These pamphlets tell us that a hectare (2.47 acres) of land, which, under indigenous grasses, would support from ½ to ¾ head of breeding cattle, will, when laid down under alfalfa, maintain from 3 to 5 head of store cattle, or from 2 to 3 steers for fattening purposes. The cost of preparing the ground, seed, and sowing of alfalfa is given at 14/7 to 16/2 per English acre, where no cereal crop has been taken off, a system largely obtaining in Córdoba and the sub-Anadean provinces for reasons that will be explained later on, but unnecessary within the cereal belt, where the actual expense incurred may be reckoned by the value of the seed. The life of the plant is given at seven to eight years in the least favourable soils, a term sufficiently long in which to communicate to the land those nitrogenous substances essential to the growth of cereals; and under conditions more conducive to longevity no decay is yet apparent.

The question now arises, what constitutes the most desirable environment for the production of alfalfa? As I have already pointed out, all soils suitable for the cultivation of wheat are found

admirably adapted for the growing of alfalfa, though the life of the plant will vary with the depth of the surface soil, and more especially with the composition of the subsoil. In the province of Córdoba, where 1,111,500 acres of alfalfa are cultivated, two conditions diametrically at variance are observable. In the eastern part, as throughout the entire Central Pampa, the surface soil maintains an average depth of two to three feet, composed of heavy, black, alluvial loam, with a little admixture of fine sand, underlaid by a stratum of plastic yellow or blue clay of immense thickness: this formation is very favourable to wheat and maize, but limits the life of alfalfa to such time as is necessary for the tap-root to penetrate a few inches into the clay, when the plant loses its vigour and gradually dies back. In the neighbourhood of Villa Mercedes, and the whole south-western section of the province, the surface soil consists of an extremely sandy, alluvial loam, varying in depth from six inches to two feet, and, if judged by the appearance of the aboriginal grasses, which are sour and sparse, presents no attractions to the agriculturist. Nevertheless, it is in these lands so uninviting to the eye that the alfalfa plant has found a habitat. The illustration does not, however, end with this particular district. Further west the broad tract of country which intervenes between the meridian passing through the City of Córdoba and the Andes is principally composed of similar lands, in much of which, notwithstanding the arid nature of the climate, alfalfa is cultivated without irrigation, the province of Mendoza accounting for 259,715 acres; San Juan for 286,520 acres; San Luis for 98,000 acres; and the territory of Pampa for 232,100 acres. As I am not an expert in the science of geology, the explanation I am able to give of this seeming anomaly, though accurate enough as to detail, will probably fall short of what an audience such as I have the privilege to address will expect.

Immediately below the surface soil, from which it differs little in composition, a stratum of saturated sand of an average depth of sixty-five feet is encountered followed by a hard seam five to ten inches thick of a calcareous deposit; underlying this seam another stratum of super-saturated sand and gravel of greater depth is met with. As a rule, a plentiful supply of water for stock purposes is obtained by sinking a pit six to nine feet, and a bore hole into the lower stratum secures a semi-artesian well. The abundance of moisture, due to the proximity of the ground water level, promotes a rapid and healthy development of the alfalfa plant in its younger stages, and the profound depth of the water-carrying subsoils ensures an unknown length to the period of its existence; many "alfalfares," known to have been planted more than seventy years ago, still rank among the most prolific in the province. I will make only one other remark on the long life of these pasturages. Some experts on the culture of alfalfa, it seems to me, attach an exaggerated importance to the extreme depth to which the roots will penetrate in a loose, well-watered subsoil. The preservation of an even and bounteous stand of alfalfa depends far more on the conditions obtaining within a reasonable distance of the surface; for when

the mechanical nature of the surface soil affords free aeration and uninterrupted capillary movement, the plant will to a large extent perpetuate itself by reseeding, always provided sufficient moisture is available in the subsoil. Irrigation in a great measure assists self-propagation, and counteracts the prejudicial effects of a heavy surface soil, but it cannot altogether eliminate the disadvantages arising from a close, heavy subsoil and a remote ground water level. A study of the map throws considerable light on the peculiarity of these water-carrying strata, for we notice at once the phenomenon that characterises the rivers of what may be termed the "Central River System."

Commencing with the rivers flowing from the north, the Rio Dulce starts in the Sierra de Aconquija in the Andes chain, traverses the provinces of Tucuman and Santiago del Estero, and empties itself into Lake Porongos on the northern border of Córdoba. The Rios Catamarca and Fiambala cross Catamarca and disappear in the sands of the province of Rioja. The Bermejo, El Zanjon, Castano, and San Juan, the most important rivers of this system, are fed from the snow-clad Cordillera de los Andes, and, flowing south-east, are lost near Lake Huanacacho, in the province of San Juan. Further south, the Mendoza, Tunuyan, Diamante, Atuel, and Desaguadero, all of which take their rise in the Andes, flow east across Mendoza into Mar Chiquita del Sur, in the territory of Pampa. The system also includes the rivers Primero, Segundo, Tercero and Quarto, starting in the Sierras de Achales, and the Quinto, whose source is in the Sierra of San Luis, all of which disappear in the south-west of the province of Córdoba.

The regularity of the phenomenon is primarily owing to the surface configuration, which is singularly level even up to the foot of the Cordillera, and these, as is the case with the mountains already mentioned, rise precipitously from the plains. I will not attempt to formulate a precise definition of the relationship between these rivers and the subterranean water found in the plains, but it seems probable that from where they disappear, the water is conducted through porous strata to the sand-beds, in which gravitation and capillarity again bring it to the surface; analogous facts on a smaller scale have been observed in other parts of the world.

It would not be possible in the time allowed me to enter at length into the vast and manifold resources of the Argentine Republic. A few items must therefore suffice to show the strides that have been made in population, enterprise, and wealth; and of these the pastoral and agricultural statistics are for the purpose of this article particularly informing.

The division of "Statistics and Rural Economies" has supplied the following particulars:—The population in 1878 totalled 1,850,000; this had risen in 1895 to 4,094,911, and in 1901 to 5,026,913. Immigration between 1870 and 1880 was made up of 260,613, which increased in 1891 to 1900 to 648,326. The length of railways open for traffic in the year 1880 was 1435 miles, a great

portion of which was the property of the State—always a suspicious feature in a new country. In 1901 there was in existence 11,000 miles, all owned by private companies. The imports advanced from £11,000,000 in 1878 to £20,607,850 in 1902; and the exports from £11,580,000 to £35,897,345 during the same period.

When trade advanced the shipping industry could not lag behind. In 1902 a grand total of 2,196 ocean-going vessels, with a tonnage of 3,973,782, left Argentine ports; while the local trade was represented by 46,735 coasters, with a tonnage of 8,954,650.

As regards cultivation, in 1872 the area under crops was 1,430,000 acres, and the country was dependent on extraneous sources for its bread supplies. Alfalfa first appears as a separate item in 1883 with 351,975 acres. In 1890 and 1901 the number of acres under tillage and permanent pasture was as follows:—

	1890.	1901.
Wheat	2,964,000	8,398,000
Maize	2,036,256	3,099,356
Linseed	93,860	1,501,760
Alfalfa	1,531,400	3,087,500
Sundries	1,363,884	1,498,047
Total	7,989,400	17,584,663

In January of this year a helpful little brochure issued by the Minister for Agriculture, gives the areas under alfalfa in 1903 at 4,829,521 acres, and in 1905 at 5,437,981; to which a foot-note is added explaining that the latter figures represent the area at the commencement of the year, and 6,422,000 acres can safely be taken as the acreage at the present time. The following table gives the amount of wealth invested in live stock since 1878:—

	1878.	1888.	1901.
Cattle	12,000,000	21,961,657	30,000,000
Sheep	65,000,000	66,706,099	120,000,000
Horses, Mules, Asses	4,000,000	4,651,526	6,100,000
Goats		1,894,386	3,100,000

The magnificent item of £35,897,345, representing the export trade in 1902, rests wholly upon an agricultural basis, as the following table shows:—

Pastoral trade	£20,907,826
Game	143,690
Agricultural products	13,634,266
Timber and mining	1,211,563

These figures are more expressive than the most glowing rhetoric in illustrating the progress of Argentina which has taken place in a little less than a single generation.

Passing now to the rise and development of the pastoral trade: In 1878 there were exported 230,000,000 pounds of wool, and a considerable quantity of hides (I have not been able to ascertain the exact amount); in 1902 Argentina's production of 511,521,920 pounds of wool was almost one-quarter of the total world's production, which is calculated at 2,231,000,000 pounds; and 103,306 tons of all descriptions of hides, together with 417,823 mares hides were exported. The freezing establishments first started an export business in 1883 with 17,165 wethers; thirteen years subsequently—in 1896—1,768,206 wethers and 7,092 steers were despatched; and in 1902 the total reached 3,429,275 wethers, and 207,755 steers. Of the frozen meat consumed in England, Argentina supplied 59.50 per cent., Australia 21.60, and New Zealand 18.90 per cent.

The live stock trade, at first confined to Brazil and the West Indies, was augmented in 1891 by shipments to Europe, and in 1892 figured at 40,000 sheep and 125,458 cattle. The advance from that date has been truly phenomenal, the numbers in 1898 being 577,813 sheep and 359,296 cattle. The appearance of the "Foot and Mouth" disease in March, 1900, caused a sensible decrease in the exportation for 1900 and 1901, which, however, was partially compensated for by an increase in the amount of frozen meat, jerked beef, and preserved meats; the two latter items accounting for 454,000 tons in 1902, when the live stock trade made an effort to regain its lost prestige with a total of 112,501 sheep and 118,303 cattle. The last item I shall refer to is one of great interest, namely, butter, of which 8,765,625 pounds were exported in 1902.

Figures of such magnitude contain not only visible evidence of the great increase in wealth, but they also point to some titanic propelling force that has assisted Argentina to outstrip all competitors in pastoral exports, and this leads up to my main contention that alfalfa is the fundamental element supporting and giving activity to the pastoral industry. The explanation becomes still more intelligible when the meat trade is dealt with under its three primary divisions of live stock, frozen meat, and conserved meats. Of these three sub-headings the live stock trade is incomparably the most important, inasmuch as the animals exported must be of the highest quality, and able to compare favourably with the cattle received from the United States, Canada, and other countries, where every art and scientific method is made use of to produce a thoroughly finished animal and the first grade of beef. What farmers in those countries are accomplishing by the aid of artificial foods and stall feeding, the Argentine farmer is doing in the open with alfalfa. Moreover, an all-the-year round trade would be impossible if the old system of grazing had not undergone a distinct change, in that the most enterprising estancieros, possessing suitable lands, had these laid down under alfalfa, and by this means elevated their businesses from that of mere cattle raising to fattening and dairying establishments.

For freezing purposes the ordinary, rough Argentine "mestizo" (half-breed), of which a large majority of the stock of export cattle

is composed, is perfectly suitable for the trade when run for a short time on the alfalfa fields: and this is particularly necessary during the winter months, when the wild grasses are hard and indigestible. As regards live and frozen wethers, every practical farmer knows that it is much more difficult to breed and finish a good steer than a passable wether, but here again the quality of the mutton has its influence on prices; furthermore, it must be borne in mind that the grade and quantity of wool yielded is an item of supreme importance, and it is gratifying to know that a short time ago the State Department of Statistics announced that under normal conditions the yield of wool per sheep had increased from 3½ to 5½ pounds since 1880.

Now I have told you a little about the most important centres of the great pastoral industry, whose ramifications have spread and have made meat almost a drug in our home markets; but these by no means exhaust the potentialities of Argentina, whose resources are only commencing their course of development. Scattered over the northern provinces there are numerous extensive, well-watered valleys awaiting a population to carry on the cultivation of the land; added to these there is the riparian province of Entre Rios, with its gently undulating plains capable of yielding almost any product, and in which, before many years elapse, alfalfa is destined to reign supreme. While south of a line drawn westward from Bahia Blanca, in the great arid desert of Patagonia, with its pebbly soil and innumerable unwholesome "salitrales" (saltpans), presenting a remarkable contrast to the calcareo-argillaceous deposit which constitutes the essential feature of the whole Pampean formation, there is no possibility that alfalfa can ever be cultivated, excepting in a few favourable patches.

We often hear it said now-a-days that the nineteenth century belonged to the United States, and that the twentieth century belongs to Canada. I hope and trust for the honour of the British Empire and the Anglo-Saxon race the prognostication will be verified, but I am constrained to think that in this great race Canada is carrying too much weight. Argentina for the most part enjoys a climate of surpassing fructuousness, the rainfall is abundant and comes at the right seasons, vegetation is growing all the year round, and the husbandman can work in the field three hundred and sixty-five days out of the year. In the quasipolar atmosphere of the "Great North West" the productive forces of nature lie dormant for more than six months out of the twelve, and the farmer, be he ever so industrious, must hibernate in much the same condition. But I rejoice to think that Canada has a rival in every respect worthy to compete with a people, whose grand old traditions and assiduous struggle against nature, have made them at once, the most sterlingly honest and lovable people it has ever been my fortune to meet, and I have travelled considerably.

In giving expression to these thoughts, I am not unaware that other persons may think I am indulging in a poet's dream, in an illusion that vanishes before the light; yet those familiar with what

I am talking about understand what I mean. Doubtless it can be argued that by a little activity of imagination, and a slight exercise of metaphysical ingenuity, it may be shown that the weakest link in the chain of circumstances making up the history of a country, has been essential to the whole order of subsequent events. But when I speak of the causations that have enabled Argentina to assume her position of proud pre-eminence in pastoral wealth, I speak of the obvious and important agency of one factor upon another, and not of remote and infinitesimal influences. The sequence of causes I have endeavoured to emphasise is threefold. First, a vast stretch of level country with a soil of marvellous fertility; secondly, the favourable environment for the economical production of the most necessary cereals; thirdly, the prodigious worth of the alfalfa plant. In these three causes we recognise the design of the Designer; and in the great prosperity of the country the deserved recompense of an industrious, thrifty, and intellectual people.

Since writing this paper "The Statesman's Year Book" gives the official returns of exports and imports for Argentina in 1905 as: Exports, £64,568,500; Imports, £41,030,800.

35—LOCUST BIRDS OF THE TRANSVAAL.

By F. Thomsen, Assistant Chief Locust Officer, Transvaal Department of Agriculture.

The following birds were described, and their relation to locust destruction, and the movement of locust swarms, pointed out :—

Glareola melanogaster.
Glareola fusca.
Dilophus carunculator.
Hirundo albigulator.
White stork.
White bellied stork.
Blue crane.
White egrot.
Bustard.
Hawks and others.

Published in the Journal of the South African Ornithological Union.

36—NOTES ON INSECT PESTS IN THE TRANSVAAL DURING THE PAST SEASON.

By C. W. Howard, Assistant Entomologist, Transvaal Department of Agriculture.

This paper discussed the life history, destructiveness and methods of combating the following insect pests:—

The Orange tree butterfly *(Papilio demoleus.)*
The lucerne caterpillar *(Colias electra.)*
The pigweed caterpillar *(Caradrina exigna.)*
Bagrada Bug *(Bagrada hilaris.)*

These accounts have been written up in more detail, and published in the "Transvaal Agricultural Journal."

37—SOUTH AFRICAN HORTICULTURE.

By T. R. Sim, F.L.S., Conservator of Forests, Natal.

The separating line between horticulture and agriculture is difficult to define. Certain crops, like grapes, cabbages, and potatoes, belong to the former when cultivated on a small scale, and to the latter when cultivated on a large scale. Other crops, like mealies and beetroot, belong to the former when certain varieties are grown for household use, and to the latter when other varieties are grown for stock-feed or milling. The two terms really overlap, and what is pure horticulture in one country or district, like plum or strawberry culture, may be as pure agriculture in another, through variation in extent, methods, and uses. In South Africa, as elsewhere, the local limitations of horticulture are somewhat arbitrary, landscape work and floriculture, as well as extensive farming operations in fruit and vegetables, being included thereunder, while agriculture covers rather the raising of crops intended for stock-feed or for milling. Garden culture as against field culture hardly applies, since the garden may be up to any size, while the field may be very small indeed, and in either case the nature of the work may be either intensive or extensive. For the purposes of the present paper, fruit, flowers, vegetables, decorative trees and shrubs, ornamental plants, and landscape art are considered under horticulture, whatever the scale on which operations are carried on.

Early History.

In the early history of South Africa horticulture evidently played a proportionately larger part in the domestic economy than it does to-day, the first settlement at the Cape having been established in 1652 by the Netherlands East India Company for the express purpose of supplying fresh vegetables, etc., and water, to its passing ships. Within a year from that date vines were imported from Europe, and during the succeeding years propagation and further importation of the vine took place largely, the stand of vine plants 35 years afterwards (i.e., before the arrival of the Huguenots) being more than half a million, though the population was then still under 500. Wine-making began before the settlement was eight years old, and brandy-making before it was 30 years old. The interest taken in the gardens at that time is shown by some of the earliest Dutch placaats, No. 5, dated December 21st, 1653, fixing the penalty for robbing the gardens at two years in chains, while No. 52, dated February 21st, 1660, fixes the penalty for injuring fruit trees at 12 months' hard labour. Even at that early date the Company imported European fruit trees, as well as oaks, pines, poplars, etc., and planted them in its own gardens, while by Placaat No. 48, 1659, "All the freemen on the other side of the river Liesbeek were ordered to enclose their lands with pega-pegas, and to plant them with wild almonds."

The early Dutch Governors appear to have missed no opportunity to import useful plants, alike from Europe and from the East Indies, and as soon as settlements were made in other parts of South Africa, Cape Town formed the centre of horticultural distribution, each pioneer family treking out into the unknown regions beyond, taking with it what was considered necessary to start a garden.

Perhaps the greatest advance ever made in South African horticulture began with the arrival of the Huguenots in 1688.

Coming from a part of Europe where horticulture formed even then a large portion of the industrial wealth, and at a time when considerable advancement had already been made in securing improved varieties, it was only to be expected, as has happened, that they brought with them stocks of the best kinds Europe had at that time, and were very careful to propagate these in the land of their adoption. This and subsequent importation during the next hundred and fifty years accounts for the good kinds of peaches, apples and pears to be found as very old trees in the oldest gardens, and variation from these occurred through using seed as well as scions to increase the number, clingstone peaches especially retaining the general characters of the old Pavie class, though varying somewhat in local seedlings from which local varieties sprang. One reason why the Huguenot families were selected or encouraged to come to South Africa was because of their knowledge of viticulture and wine-making, the fact that the vine grows well at the Cape having previously been demonstrated. The number of vines increased about six-fold during the first 20 years of their residence, and the export of Cape wines dates from that period (say 1707). The old oak trees in the Avenue, Cape Town, are probably among the oldest horticultural specimens now extant in South Africa, dating from Simon van der Stel's time (1679-1699), as also does the well-known estate of Constantia. From that time onward introductions continued to dribble in slowly, no notable boom in importation having occurred till quite recently, though few really good and suitable European novelties failed to be represented in some South African collection, and to be distributed in accordance with merit and adaptability.

PLANT COLLECTIONS.

From 1770 to 1820, however, the flow of plants took the opposite direction, the extraordinary wealth of South Africa in certain floral lines having attracted attention and brought numerous and ardent collectors both of living plants and of dried specimens, to these shores. Besides private collectors, the Royal Gardens, Kew, and the Royal Horticultural Society, several nursery firms were represented, and the material sent home, including as it did many species of Pelargonium, Proteaceæ, Mesembryanthemum, Oxalis, Helichrysum, Gladiolus, Ixia, Crinum, Agapanthus, Clivia, Kniphofia, Bulbine, Gloriosa, Aloe, Asparagus, etc., created quite a sensation, and brought into existence a very miscellaneous and meritorious

group known as Cape plants. Considering the limited range and the difficulty of transportation of some of these kinds, especially Heaths, it is a matter of surprise that they ever reached Europe alive, but once there the highest skill in horticultural propagation and culture was brought to bear on them, with the result that finer displays of Cape plants were common then in Europe than have ever yet been brought together in one place in South Africa, these exhibits being seldom surpassed even now. Hybridization, and the selection of sports in broken species, also came into play, with the result that many grand varieties which have never been seen in Africa have been secured from Cape parents.

Fashions change, and Cape plants are no longer thought of as one group; some of them have gone out altogether, but others still hold their own, especially Bulbs, Pelargoniums, and some Ericas, and form leading features in the horticultural trade of Europe and North America at the present time, propagated in these countries, and seldom grown here for export.

LATER HISTORY: BOTANIC GARDENS.

It is part of Britain's system of colonization that a public garden, usually under the name of a "Botanic Garden," acts as a centre of importation, acclimitization and distribution of plants, wherever a considerable community has settled, which does not possess an energetic nurseryman in its midst. Such has happened at many centres in Cape Colony, and at two in Natal, while public parks have answered somewhat the same purpose in the Transvaal and Orange River Colony. Aided by Government grants, these establishments have done very useful work, and in most cases contain specimens of numerous kinds—especially of trees and shrubs, not elsewhere represented in their respective neighbourhoods—and thus form object lessons of the first importance. In some cases these have withdrawn from public competition in nursery work after a satisfactory local supply was established by private effort, and then simply exist on the Government grant or local contributions; in other cases they use the Government grant in raising ordinary nursery stock for sale as a means of existence, and thus by State aid prevent the development of a local industry of this nature; while in a small number of cases they have themselves developed into important nurseries, managed nominally by Committees, but actually by the Curators, and in these cases the Government grant is rightly used in the maintenance and development of the botanic garden proper, while the nursery is self-supporting or even profitable, any profit derived going towards increased effort, or adding to the charm of the garden itself. Usually these Botanic Gardens and Public Parks have done much to foster a love of horticulture and render its practice possible; unfortunately, inadequate provision of funds and over-ambitious committees have in not a few cases saddled these establishments with White Elephants which could not exist on the Government

grants, and had to earn their living as best they could. One of the best services rendered by these institutions has been the importation of trained men to act as Curators or Assistants, and who, either in these positions or afterwards, have been leaders of horticultural life throughout South Africa.

NURSERY TRADE.

The nursery trade itself is a very recent innovation in South Africa, but one which has grown rapidly since it started, and has still an enormous field for expansion.

Twenty-five years ago the Botanic Gardens did practically all the Nursery business done, and they joined with private florists in complaining when the Cape Government Forest Department, about 1885, began the sale of forest tree transplants at cost, in order to render possible more extensive tree-planting than had previously been practiced. That trade has increased enormously in the hands of the Forest Departments of Cape Colony, Transvaal, Orange River Colony, and Natal, and the public find that they have now in that line sure and reliable supplies, while even the nurserymen are not disappointed in being relieved of what often proved the unprofitable part of their business, leaving them free to take up much more profitable lines with greater energy and advantage. And it is only those nurserymen who have broken away from the conventional, many-sided class of trade, and specialised in a few leading lines, who can be said to have done passably well. The expense connected with the maintenance of an all-round trade has been too great for the comparatively limited demand, and is likely to remain so till the population grows. But in regard to fruit trees (especially citrus trees), Roses, Palms, Table Plants, and a few florist lines, there is a standing demand which always justifies practical labour, and allows reasonable prices to come in.

FRUIT CULTURE.

Reasonable prices are, however, of comparatively recent adoption. Fifteen years ago 10/- was not an uncommon price for an orange tree, or 3/6 for a deciduous fruit tree, and over-grown trees were more in demand than maidens. But Cape Colony had the advantage soon after that date of having, among its new arrivals, several Californian fruit growers, who were not slow to introduce new life and energy wherever they settled. South Africa owes much to these men, who, realising the grand climate and the unequalled geographical and seasonal advantages for fruit culture, helped others as well as themselves in building up the first foundations of a wholesale deciduous fruit industry. The late Cecil Rhodes saw what was in it, and invested largely, and others gained confidence from his

lead. It so happened that Phylloxera at that time threatened the vine industry, Australian Bug and Mal-de-gomma had practically cleared out the citrus groves of the Western Province, and generally Agriculture was unremunerative, so the deciduous fruit industry—though not altogether new—received a further impetus as a probable salvation, and as a substitute for discarded vines and oranges. All this meant a large demand for trees, and allowed propagation on systematic American methods on a scale hitherto unattempted here, giving profitable business, though prices were reduced 50 to 75 per cent. Then may be said to have occurred the only recent boom in importation, fruit trees from America, Europe and Australia coming in considerable quantity and in considerable variety.

Fruit trees require time to develop, and it is only recently that the large plantations then put down have begun to yield in quantity and to show what can be done. It was freely predicted that what would happen would be the annual swamping of all South African markets at glut prices, and shipment of only the best to Europe or elsewhere. What has actually happened has been that instead of unduly pushing export, full prices have been obtained for first-rate fruit in every South African market, with fair demand and few gluts, and that the low-grade and badly-handled local material stands in marked contrast both in quality and price to that systematically handled, wherever they appear side by side. Growers everywhere now realise that fruit has to be good and clean, and to be properly handled and packed if it is to realise other than low prices, so, thanks to easy transport, the improvement begun in the South-West is now having its effect quite as much in the Transvaal and Natal as in the Cape Peninsula and neighbouring districts.

There is a demand everywhere for first-rate fruit, corresponding in extent with the population of the district; that demand is met from a distance if it cannot be met locally, and since the local supply is ousted unless it is good enough to keep out that on which freight and package has been paid, better kinds, better trees, and better treatment, are coming into use much more generally, and must continue to do so.

Fruit-culture, from being a farmer's or tradesman's hobby or pastime, is rapidly becoming an important industry, requiring attention to every detail at the proper time, and an up-to-date plant, to cope with it.

And this holds good in respect to other lines as well as to deciduous fruit, for as citrus fruit and tropical fruit are easily moved within South Africa, and as the best naturally secures the best price, irrespective of where it has come from, improved culture is forced on growers all round if they wish to sell.

It may be said without doubt that the best varieties of all hardy and semi-hardy fruits are now obtainable as well in South Africa as elsewhere; what remains to be proved is which of these varieties in

each case does best under local conditions, and best meets the requirement.

As a step towards ascertaining these points, the respective Governments have each arranged something in the nature of trial plots, in which greater variety is introduced than would usually be done by a private grower or even by a nurseryman. In the Transvaal some 400 varieties are on trial, in Natal about 1000 varieties, while in Cape Colony a smaller number of selected kinds is being distributed for trial at many centres.

It is generally conceded that only a few varieties are wanted at one place, but the point in this experiment work is to find which are the few kinds best worth attention in each locality. Experience in America, Australia and elsewhere has been that each locality eventually produces locally a few kinds best suited to itself, or selects and adopts as its own a few chance trees of unknown history but of special quality.

And in this selection not only has the effect of local conditions on all available varieties to be tried, but the special requirement of the market to be supplied has also to be considered, for it is surprising how some kinds are in demand in one market, and unsaleable in another.

Proving these problems is public work if the Colony desires to benefit, otherwise a few energetic men control the trade and make the profit, and the public is left out.

Experiment work in other directions, as to soils, fertilizers, pruning, cultivation, espacement, irrigation, intercropping, shelter, stocks, packing, cold storage, transport, etc., are also in hand as Government work, and each Government has an officer in charge of such work.

EXPORT OF FRUIT.

After a century of slow progress, fruit culture made a fresh start when, in 1889, a first attempt was made to ship fruit to England on a commercial scale. The Castle Steamship Co. responded to the growers' demand by fitting up in one of its steamers a cool chamber with a capacity for 30 tons. Whether the growers filled this or not does not appear, but the *Cape Agricultural Journal* (Vol. II., page 208) contains a report, dated March 11th, 1889, by Mr. J. Willard, Member of the Fruit Committee of the Royal Horticultural Society, to the Secretary of the Cape Agricultural Society, on a trial shipment of apparently three cases of fruit, which included Grapes, Pears, and Melons, the two latter being in one box. During the next two years export business was still in the initial experimental stage, but in 1892 some 500 cases of fruit in variety were shipped, and the results led both the Castle and the Union Steamship Companies to fit up cool chambers of 60-ton capacity in each of several steamers for the next year's trade, when a large business at once sprang up.

Information in hand, which is unfortunately incomplete, shows the subsequent oversea trade as follows:—

		1892–3	1893–4	1894–5	1895–6	1896–7	1897–8	1898–9	1899—1900	1900–1	1901–2	1902–3	1903–4	1904–5
Apples	packages	526	180	...	...	...	...	...	...	...	29	22	47	138
Apricots	"	481	24	433	...	...	...	...	...	...	110	32	1,220	403
Citrons	"	1	...	...	...	...	...	...	...	...	...	...	...	...
Gooseberries	"	...	1	...	...	...	...	...	...	...	...	...	...	...
Grapes	"	10,896	6,283	...	...	...	...	...	...	...	5,896	9,043	7,641	7,197
Grenadillas	"	21	1	...	...	...	...	...	...	...	...	...	...	1
Guavas	"	...	...	...	...	...					...	...	...	1
Lemons	"	1	...								12	...	...	...
Melons	"	181	117				do.	do.	do.	do.	...	...	...	8
Naartjes	"	...	...								1,999	...	...	...
Nectarines	"	30	23		do.		do.	do.	do.	do.	568	1,401	1,209	404
Oranges	"	58	...								10	...	...	...
Pears	"	654	382	Incomplete Information.		Information not in detail.					746	705	3,177	5,048
Peaches	"	2,428	576								2,512	3,276	7,876	2,918
Pine-apples	"	3	7								23	...	...	23
Plums	"	7	1		do.		do.	do.	do.	do.	3,068	7,457	13,553	6,340
Pomegranates	"	5	...								...	3	...	...
Quinces	"	206	31								25	29	...	33
Tomatoes	"	2,717	57								...	...	...	18
Persimmons	"	...	...	...	...	...	...	...	...	...	...	...	...	1
Total number of Cases		18,215	7,683	?	?	?	9,169	10,817	17,336	17,263	14,998	21,968	34,723	22,533
Total value entered ...		£6,704	£1,721	?	£7,831	£6,025	£4,100	£4,500	?	?	?	?	£8,000	£6,109

From these figures it looks as if the trade for 1902-3 had been unremunerative, and had reduced the export in the following season,

but the true explanation is that the prohibitive Transvaal duty was removed in time for the 1903-4 trade, and the growers naturally took that market in preference to Europe, overdoing it, however, and causing a slump for that year. But even in recent years the English trade does not show such expansion as might have been expected, and prices for the present year (1905-6) have not been satisfactory. This may be accounted for partly by cold weather at the time of arrival, partly by unsatisfactory distribution arrangements, partly by too high expectations, and partly by the nature and condition of the fruit itself, for even after all these years of experience some shippers have still to learn that only certain kinds command the London market at any season, and that it only pays to ship the best, and that only if graded to a reliable brand.

Since 1904 an endeavour has been made to open up a market in continental Europe, as also in North America, fruit being transhipped at Southampton to prevent delay; but thus far the demand remains small, and fruit from the Argentine at the same season may affect these markets in the near future. The fact that the Cape Fruit Exporters' Association ships almost the whole export, and that into one London office, seems to be an arrangement possibly open to improvement, while, on the other hand, London Agents interested in West Indian, Canary, Australian and other goods, prefer to ignore Cape fruit, lest it interfere with their own established connections.

That the oversea export deals with only an insignificant proportion of the whole production is proved by figures showing the destinations of fruit sent from the Western Province Railway Stations during fruit season 1902-3, as follows (*Cape Agricultural Journal*, XXIII., 83):—

To Docks	231½	tons.
To stations in Cape Division	5,928	„
To stations between De Aar and Kimberley, inclusive	1,052½	„
To stations north of Kimberley	228	„
To stations in Orange River Colony ...	337½	„
To stations in The Transvaal	2,125½	„
To stations in the Midland system ...	210½	„
To stations in the Eastern system ...	181½	„
Total weight to all points ...	10,295	tons.

The Cape Colony naturally has by far the largest area in fruit, the figures, according to information kindly supplied by the Agricultural Departments of the respective Colonies, being about as follows, including trees and vines scattered around homesteads, viz. :—

	Fruit Orchards.	Vineyards.
Cape Colony (1904 census)	37,985 acres.	35,297 acres.
Transvaal (1904 census, allowing 100 trees or 430 vines per acre)	23,255 „	1,000 „
Orange River Colony. Statistics not	available, area	small.
Natal, approximately	34,000 acres.	50 „
Rhodesia	800 „	5 „

Except for citrus and sub-tropical fruits which belong to the North-Eastern portions of Cape Colony, Natal, Transvaal and Rhodesia, the fruit districts are located in the South-Western part of Cape Colony, where the wet winters, dry summers and rich, suitable soils, give conditions probably unequalled elsewhere, though deciduous fruits do well throughout colder South Africa. Among the districts of Cape Colony, the following is the order in which they are placed by area under fruit trees, vines and vegetables, respectively, expressed in morgen, as shown in 1904 census, viz. :—

FRUIT ORCHARDS.

Paarl ..	...	2,353½	Morgen.	Cradock	..	297	Morgen.
Stellenbosch	...	914¼	„	Robertson	...	293½	„
Caledon	...	692	„	Albany	...	286	„
Worcester	...	671¼	„	Aliwal North	...	281¾	„
Bathurst	...	530	„	Queenstown	...	279½	„
Clanwilliam	...	445¾	„	George	...	264¾	„
Elliot	...	420½	„	Cape	...	260½	„
Piquetberg	...	419	„	Ceres	...	259½	„
Oudtshoorn	...	402½	„	Calvinia	...	249½	„
East London	..	400½	„	Middelburg	...	246	„
Albert	...	391¾	„	Graaff-Reinet	...	243	„
Humansdorp	..	388½	„	King Williamstown		234	„
Wodehouse	..	385	„	Somerset East	...	222	„
Uniondale	...	378½	„	Riversdale	...	219¾	„
Uitenhage	..	366½	„	Richmond	...	207½	„

19 other districts between 100 and 200 and all others under 100 morgen each.

VINEYARDS.

Paarl	..	3,782	Morgen.	Caledon	...	315½	Morgen.
Stellenbosch	...	2,100	„	Ceres	..	288¾	„
Worcester	...	2,304½	„	Swellendam	...	257¾	„
Robertson	...	1,669½	„	Clanwilliam	...	226½	„
Piquetberg	...	1,475½	„	Ladismith	...	201¼	„
Cape	...	994½	„	Van Rhynsdorp	...	137¾	„
Malmesbury	...	900¾	„	Prince Albert	...	125½	„
Tulbagh	...	460¾	„	Graaff-Reinet	...	113½	„
Oudtshoorn	...	443	„	All others under 100 morgen.			

VEGETABLE GARDENS.

Stellenbosch	...	661	Morgen.	Uitenhage	...	172½	Morgen.
Cape	...	648	„	Calvinia	...	146¾	„
Ceres .	...	514½	„	Worcester	...	138½	„
Malmesbury	...	376¾	„	East London	..	124¾	„
Paarl	...	362½	„	Bredasdorp	...	123¾	„
Port Elizabeth	...	329½	„	Cradock	..	112½	„
Caledon	..	223½	„	Piquetberg	...	108¾	„
Clanwilliam	...	186½	„	Middelburg	...	103½	„
Oudtshoorn	...	179¾	„	Albany	...	100	„

A very considerable proportion of the fruit trees have been planted within the last few years, and are not yet in bearing, the proportion in the largest fruit districts—Stellenbosch, Paarl, and Wellington—being about half. The comparative production of

different fruits throughout Cape Colony is approximately shown by the following figures, also from the 1904 census :—

Kind.	Number of Fruits.	Districts in order of largest production.
Oranges ...	35,006,263	Humansdorp, East London, Bathurst, Paarl, Clanwilliam, Swellendam, Oudtshoorn, Uitenhage, Uniondale, Robertson, Albany, King Williamstown.
Lemons ...	3,492,678	Paarl, Stellenbosch, Piquetberg, East London, Humansdorp, King Williamstown.
Apples ...	20,832,133	Paarl, Humansdorp, Stellenbosch, King Williamstown, Uniondale.
Pears ...	7,567,906	Stellenbosch, Paarl, Uniondale, Bredasdorp, Robertson, Oudtshoorn, Riversdale, George, Worcester.
Peaches ...	23,180,096	Paarl, Stellenbosch, Oudtshoorn, Worcester, Uniondale, Riversdale.
Apricots ...	33,731,940	Paarl, Malmesbury, Stellenbosch, Graaff-Reinet, King Williamstown, Worcester.
All others ...	70,321,601	Paarl, Stellenbosch, George, Worcester, Bathurst, Tulbagh, Uitenhage, East London.

In the other Colonies statistics are less detailed, but the number of trees standing is approximately :—

	Deciduous Fruit Trees.	Citrus and other sub-tropical fruits.	Vines.
Transvaal	2,024,018	301,522	430,383
Natal	2,000,000	2,000,000	21,500
Rhodesia	60,000	20,000	2,500

The Customs returns indicate what becomes of the Cape produce in so far as not used for domestic requirements, viz. : for 1904 :—

	Oversea exports.	Value.	Exports to Colonies in the Customs Union.	
Jams	44,243 lbs.	£999	£8,745	(mostly to O.R.C.)
Fruit, bottled	434 „	31	71	
dried	32,100 „	437	9,947	
fresh	?	7,960	79,823	
Nuts	6,207	156	1,557	(newly started).
		£9,583	£100,143	
Total ...		...	£109,726	

But against this the imports show that there is still scope for enormous expansion in preserving, and that there is also considerable import of fresh fruit still going on, viz. (Cape Colony, 1904):—

Jams	1,571,375 lbs.	£21,324
Fruit, bottled	699,713 "	13,507
dried	1,573,972 "	21,937
fresh	?	38,216
		£94,984

while each of the other Colonies shows a similar tale.

The production of dried fruit in Cape Colony is, according to 1904 census:—

Kind.	Weight.	Districts in order of largest production.
Raisins ...	1,838,330 lbs.	Worcester, Robertson, Oudtshoorn, and Ladismith.
Apricots ...	237,621 "	Paarl, Worcester, Tulbagh, and Malmesbury.
Pears ...	317,377 "	Clanwilliam, Uniondale, Calvinia, Ceres, Ladismith, Fraserburg, Prince Albert.
Apples ...	156,617 "	East London, Clanwilliam, Ceres, Uniondale, Calvinia.
Peaches ...	1,202,480 "	Clanwilliam, Oudtshoorn, Ladismith, Prince Albert, Robertson, Worcester.
Prunes ...	176,070 "	Paarl, Worcester, Stellenbosch.
Mebos ...	43,948 "	Paarl.
Others ...	156,050 "	Paarl, Oudtshoorn, Calvinia, Caledon.
Total ...	4,128,494 lbs.	

The Natal fruit product is mostly of coast fruits, such as oranges, naartjes, bananas, pineapples, etc., and may value somewhat over £150,000 per annum, according to present methods of sale, or much more if graded, clear of pests, and properly handled.

But the import of fruit, either fresh or preserved, has been quite as much during each recent year.

Cape fruit growers have two local boards, the Western Province Horticultural Board and the Eastern Province Horticultural Board, with a congress occasionally; at all these meetings the discussion of horticultural subjects takes second place to bringing pressure to bear on the Government to do for growers much of what by co-operation they ought to do for themselves. The Cape Fruit Exporters' Union takes practical action, co-operative local sale depôts have begun to

appear at various centres, electric plant is installed in several orchards and factories, and the Harbour Board provides cold storage at Cape Town Docks pending shipment.

More co-operation, more information, more preserving, more of the best, less of the worst, and less of Government aid except in experimental work, are the desiderata in connection with the fruit business at the present time. Development of fruit export must be persevered in, even if unprofitable at present, in order to have a market prepared by the time larger crops come in; but it is also important—probably more important—to have the local demand fully supplied all the year round, with good material from local sources, even by cold storage, and to oust the wretchedly bad seedlings which mainly breed pests and have no commercial value.

South Africa is a fruit country throughout, but each locality has its own possibility, and it is only by studying these, and working thereon, that success can be looked for. South Africa is meantime its own best customer, but the time is not far distant when foreign markets must be forced, at lower rates than those prevailing here, but still at paying rates if systematically handled.

VINES.

As already mentioned, portions of the Western Province are among the best vine districts in the world, the climate and soil being unequalled, and the yield per acre proportionally good. In the Eastern Province, Natal, and the Eastern Transvaal the summer rains interfere seriously, and vine culture is not likely to become a large commercial business there. Even in the Western Province the product is almost a natural one, very little trouble being taken to produce high quality, with the result that in European markets the Cape dessert fruit, despite its splendid flavour, is considered poor, through the crowding of small berries and the presence of what should have been thinned out. London agents also complain that shipments arrive in very unequal condition, fruit raised under artificial irrigation being inclined to suffer during the voyage, but probably the kind rather than the treatment has to do with this, for kinds grown in different districts vary considerably. In one English report it is stated that Cape grapes have a bad reputation now, which will take some time to do away with. According to the 1904 census, the stand of vine-stocks in the Cape Colony is 77.893,187 plants, of which 19,237,259 are grafted on Phylloxera-resistant stocks, and 58,655,928 are ungrafted. There are only two districts in which the number of grafted is more than that of ungrafted, viz. :—

Paarl	9,553,302 grafted.	3,986,743 ungrafted.
Stellenbosch	5,383,423 „	2,903,575 „

In the two vine districts next in importance the conditions are reversed, viz. :—

Worcester	634,700 grafted.	12,878,825 ungrafted.
Robertson	36,750 „	12,722,017 „

The other important vine districts are arranged in accordance with number of stocks:—Malmesbury, Cape, Tulbagh, Oudtshoorn, Piquetberg, Ladismith, Caledon, and Swellendam, the number of plants in these varying from five million to two million each.

The districts in which haanepoots form a large proportion of the stand are Worcester, Robertson, and Oudtshoorn, with 6,578,150, 3,315,072, and 1,520,635 haanepoots respectively, while in the Paarl, Stellenbosch, and all the other vine districts they form only a small proportion of the whole. This is reflected in the product of raisins already referred to, which are mostly produced in Worcester, Robertson, Oudtshoorn, and Ladismith.

Taking the Cape Colony as a whole, the vine stocks are classified:—

Red Wine:	Hermitage	...	7,286,089
	Pontac	...	565,139
	Muscadel	...	6,815,415
White Wine:	Stein	...	4,297,702
	Greengrape	...	22,384,376
	French Grape	...	8,297,308
	Haanepoot	...	17,493,974
	Others	...	10,753,184

The produce is entered as:—

Grapes made into wine or brandy	...	5,809,609	baskets.
Grapes not made into wine or brandy	..	467,316	„

Wine:	Red	...	1,460,721½	gallons.
	White	...	4,225,950	„
Brandy or Spirits		...	1,534,069½	„
Vinegar		...	114,015	„
Raisins:	Stalk	...	60,520	lbs.
	Loose	...	1,726,895	„
	Sultanas	...	43,116	„
	Currants	...	7,794	„

The oversea export of wine is entered at 73,655 gallons, value £18,457, while to the other Colonies in the Customs union it is:—

Wine:	Hermitage	...	£3,556
	Constantia	...	226
	Other kinds	...	47,495
Spirits		...	39,703

Making a total export of wines and spirits of £109,437 value.

The import of wine is 65,862 gallons, valued at £47,591.

The grapes produced in the Transvaal, Orange River Colony, Natal, and Rhodesia, are almost entirely used for local table use, wine forming at present only a very small product.

VEGETABLES.

The area under vegetables in Cape Colony has already been stated as 15,410 acres, and the distribution of this is shown in a previous page. With such an area in crop, and with much more

available, it is a standing disgrace that over 1000 tons of preserved vegetables should be imported annually into Cape Colony at a cost of about £25,000. Each of the other Colonies is also an importer, though possessed of much suitable land for growing vegetables. Beyond growing for the respective local markets, the only commercial vegetable culture is that of onions, and of a few cabbages and cauliflowers for Kimberley and Johannesburg. Vegetable culture, as it is known in the United States and the Channel Islands, is non-existent, but the import indicates that there is scope for many unskilled gardeners taking up this easy and often profitable work.

The onion product of Cape Colony amounted in 1904 to 123,175 muids (one muid = 3 bushels), the districts supplying the largest quantities being:—

Caledon	...	24,948 muids.
Tulbagh	...	20,248 „
Stellenbosch	...	15,315 „
Worcester	...	12,322½ „
Paarl	...	11,887¼ „
Cape	...	9,834¾ „
Robertson	...	7,775½ „

All other districts producing less than 2,000 muids each.

The onions exported from Cape Colony during 1904 were:—

Oversea	...	448,571 lbs.	value £1,713
Overland	...	?	£21,427

and of onion seed raised in the Cape Colony, £259,

while the import (not included above among vegetables) was 611,343 lbs., value £2,003 (784 tons less than in 1903).

Of other vegetables the overland export was £13,052 value, but an item of £10,713 appears for Garden, Vegetable, and tree seeds among the Cape Imports.

Generally speaking, vegetable culture for domestic use is neglected, vegetable culture for market is in the hands of a limited number, often Malay, Chinese, or Indian coolies, and the production of local seed from selected types has still to be begun.

PLANTS, FLOWERS, TREES, ETC.

A curious item in the annual list of exports from Cape Town is "Everlasting Flowers," which for 1904 were entered at 170,316 lbs., value £12,012. These 85 tons of flowers are not the result of cultivation, but the collection of many hands from indigenous plants on the South-Western mountains. Apart from this the demand for flowers is purely local, and has nowhere assumed large proportions. The florists' catalogues contain practically everything known to suit the local conditions, and domestic amateur floriculture is well practised, and often highly successful, but as a business floriculture has not yet caught on.

The same may be said concerning decorative plants, ornamental trees and shrubs, herbaceous plants, succulent plants, and even bulbs.

Suitable kinds do well, and the general effect is highly successful, but select strains of florists' flowers are almost absent, and such trees and shrubs as require propagation by cuttings are rare as compared with seedlings. There are practically no landscape artists, and there is no demand for such, and even European gardeners are few, and often unsatisfactory.

Horticultural information is not available, except from interested nurserymen's catalogues, or from foreign works or magazines, in which the seasons seldom correspond with ours.

PESTS AND OTHER TROUBLES.

In regard to damage done by Phylloxera in the Western Province, after a prolonged and unsuccessful campaign against the pest by means of carbon-bisulphate or other treatments, some measure of success has been again secured by the introduction of American Phylloxera-proof kinds, and their use as stocks for the better kinds, but even now it is found that there is still something to be learned in regard to the continued success of certain kinds on certain stocks. This also applies to citrus culture, in which much has still to be proved in regard to suitable stocks and their ability to resist mal-de-gomma, a class of experiment which naturally takes many years before it gives final results with regard to any one place, and as it may be easily affected by some unnoticed local condition, has to be carried out at many centres before general success can be assured.

Horticulture is not without its troubles, both animal and fungoid pests being usually in evidence, as well as inimical local climatic and soil conditions in places. When Phylloxera appeared, stringent import regulations were imposed, practically prohibiting the import of all plants. These regulations, which did little good to viticulture, the disease being already present, did much harm to horticulture in general, all novelties being for the time excluded, except by smuggling. An Entomologist was appointed at that time for the Cape Colony, and later an Entomologist was appointed for each of the other Colonies; these gentlemen or others having also charge of the fungoid and bacteriological diseases of plants. Under their care regulations are now in force intended to prevent the importation of further pests into either Colony, to prevent the spread from nurseries of what pests already exist, and to prevent the spread of Codlin moth and certain other pests beyond areas already affected.

Public opinion is gradually working toward the necessity for legislation against the breeding of pests by private growers to the detriment of their neighbours' gardens or orchards, a step quite as necessary as legislation against scab in sheep, or against other infectious stock troubles, but quite as difficult to attain, since it touches practically everyone's private garden, and means work.

No country is without its pests; South Africa is in no worse position than others, except that the lackadaisical habit is strong in humanity. The preventive or curative treatments are well known or

easily ascertained; the difficulty is to get them applied, except by compulsion, and until they are generally applied progress cannot be expected.

GENERAL.

Horticulture in South Africa is only on the threshold of progress. In every line there is scope for improvement; in most lines possibilities are enormous. The climate varies from tropical to cold temperate, the rainfall from nothing to 60 inches, and the soil and subsoil vary immensely; the range of available kinds is consequently very large.

But the population is small and scattered, and the literature altogether inadequate. The Departmental Agricultural Journals of the respective Governments are highly useful in so far as they touch on fruit-culture and viticulture, but they leave the other lines almost out, and even in these lines red-tape prevents free discussion where Government action or non-action is concerned. An independent, inter-colonial Horticultural magazine for South Africa would fill what is meantime an empty void, and do good not only to the commercial fruit grower, but also to the amateur and to the numerous class whose members claim to know by natural intuition much more than the professional man trained abroad, and sometimes show that they do so. An occasional inter-colonial conference of fruit growers is also a desideratum, at which practical work rather than parish politics should be discussed, for it is evident that South Africa requires all to pull together for action in this as in many other matters, rather than lose time in petty jealousy. Cape Colony meantime has the lead in hardy fruit culture, and supplies the other Colonies after their supply is finished, but there is no inherent reason why Cape Colony should not be also supplied with fruit from the other Colonies months before its own supply is ready, and so by reciprocity allow each Colony to enjoy a longer fruit season and live upon fruit more than it does at present.

A Conference as proposed above, representing alike the affiliated Horticultural Societies of South Africa and the nursery and fruit trades, would soon take up the central position in South Africa meantime held in England by the Royal Horticultural Society, and would do more to stimulate horticultural work than any agency meantime in existence.

38—SMOKE ABATEMENT IN MINING AND MANUFACTURING CENTRES.

By Arthur H. Reid, F.R.I.B.A., F.R.S.I.

I have for some time, both at Johannesburg and at Cape Town, watched the constant increase of smoke clouds, and as one who has given the matter of Public Health some attention, I have come to the conclusion that the cause of the same is preventable, and the effect both detrimental to health and wasteful. Any person who has eyes and uses them, must have noticed the clouds of smoke that hang about the environs of Johannesburg when a southerly wind is blowing, and in the early morning how the low lands north of Bellvue are hidden from view not by mist but by smoke clouds, held more or less in suspension by mist or atmospheric influence.

To be rational, I will take the *cause* of this nuisance or waste first, and in doing so it must be understood that I am not posing as an engineering expert, or as an authority upon the subject under review, but simply venture, as a commonsense individual, to attract the attention of other thinking people to a matter that strikes me as being wrong in every sense. Should my effort result in producing a discussion between our engineering friends who may lay bare facts that I hesitate to adduce, my reward will be secured.

It is surely only commonsense to submit that smoke fog is nothing more or less than particles of carbon or unconsumed coal, and that their presence is due to the imperfect combustion or consumption of coal from one cause or another. Commonsense will also allow that such fog is detrimental to the health and comfort of those whose lives have to be spent in contact with it, and I shall prove, later on, that its presence has much to do with the high cost of production and reduction of our gold ores, and, indeed, of industrial productions generally. I do not propose to touch upon the destructive effect of smoke upon animal or plant life, though I venture to hope that my remarks may produce some valuable evidence of the future danger its presence suggests if precautions are not taken to prevent its increase.

I submit, as nothing new, that the present system of having so many steam-power installations for the working of our mines and industries, instead of installing a few large power houses, is the primary cause of the trouble I have named. By centralising the electric or other power stations the production of smoke must be reduced, first, on account of the great distance between smoke stacks; secondly, because the methods of fuel combustion can be better supervised; and, thirdly, because less coal will be consumed. Electrical distribution of power, oil, hot air and internal combustion gas engines, naturally suggest themselves as smoke-reducing schemes, and it must indeed be a source of gratification and pride to our Johannesburg Municipal Council that they have been among the first to shew their appreciation of that fact by adopting gas engines for the generation of Electric Power for the Municipal Tramways and Lighting schemes.

In England and on the Continent it is generally allowed that the greatest producers of smoke in the cities and towns are the domestic grates, but here it must be admitted that our mining and industrial works are the chief offenders, and it is with the keenest sympathy and hesitation that I venture to attack the system, not the works!

Let us now consider the *cause* of an abnormal production of smoke in furnaces.

Firstly, we must indite careless or ignorant stoking; secondly, the use of improper coal or fuel; thirdly, the use of obsolete or badly-designed fire-boxes; fourthly, defective draught, due to choked tubes or defective flues; fifthly, the want of scientific supervision of Furnaces and Boilers by the Managing Engineering Staff.

Then let us consider the *effects* of the same from a scientific point of view.

The merest engineering student knows, or ought to know, that bituminous coal can be completely consumed so as to emit no smoke, (a) by heating and regulating the supply of air to the furnace, (b) by securing and maintaining a proper temperature in the furnace, and (c) by properly controlling the gaseous products of combustion in their passage to and up the chimney.

It has been publicly reported that Messrs. Crossfield and Sons, of Warrington, have, by adopting a scientific treatment of their fuel and stoking, saved 1000 tons of coal per week, which means that they were saved the use of almost double the number of boilers, with all attendant expenses of depreciation, firing, upkeep, etc., which amounted in all to about £25,000 per annum, and the Cardiff Railway Company admit that their saving of fuel amounts to 25 per cent. The points observed by these consumers have been the proper construction of furnaces, flues and chimneys, the regulation of air supply, mechanical and careful stoking, the preparation, elevating, and conveying of fuel, the heating of feed matter, and careful supervision by their senior engineers.

The point I wish to bring home at this time, when the saving of working costs is our great problem, is, if a single coal consuming firm can effect the saving I have quoted, what would be the saving to our great gold industry and other industrial concerns if their example was followed?

Human nature is hard to drive but easy to lead, if met in a rational manner. There is a class of person, unfortunately too numerous, who resents anything like interference, and such is most difficult to deal with, because out of "pure cussedness" they will do all they know to evade restraint, and look upon advice as an impertinence. The conceit that is born of ignorance is the bugbear of progress, science, and economy, and probably justified the inception of the Public Health Act (England) 1891, which fathered that splendid fighting body known as the Smoke Abatement Society. If only for economic reasons, I submit that such a body should be

immediately formed at Johannesburg under the patronage and financial support of the Gold Mining Companies and Chamber of Mines. It should not be difficult in such a commonsense community as ours to prove that money can be saved and dividends increased by preventing the discharge of the thousands of tons of unconsumed carbon which, I submit, is anything but creditable to our engineers, though it may be profitable to the colliery owners, and save our firemen some trouble.

We all realise that legislation can be made obstructive and destructive of the very object it has in view, but it cannot be denied, I think, that without legislative power behind it, persuasion, argument and commonsense would be of little avail. After all, engineering science is little more than commonsense, backed up by education and experience, all of which we claim. Yet it seems to me that the practical application of those attributes to our interests, as a community, is sadly neglected.

Last year the English Coal Smoke Abatement Society issued a series of questions to manufacturers and others, with a view to ascertaining the causes of waste and the best means of counteracting the same. The Society was, I believe, careful to select many manufacturers for their enquiries who had at one time or another been serious offenders against the Public Health Act. A typical reply to the circulars acknowledged that even when so-called smokeless coal is used, smokeless combustion cannot be secured unless both boiler and furnace are scientifically designed, and the stoking carried out with intelligence and care. Great circumspection was exercised in the selection of suitable stokers, and special attention had been given to the training of these men at their works, under the close inspection and instruction of their engineers. By way of encouragement, higher wages were paid to firemen who shewed exceptional ability, and it was acknowledged that such increased wages were more than saved by the economy in fuel and the extra power secured by the services of the more intelligent and conscientious stokers. It was further acknowledged that the better class of firemen fully appreciated the necessity of studying the elementary science of combustion and the different classes of fuels, so that it mattered little to him where he was located, as he was more or less conversant with the peculiarities of all classes of fuel, and soon ascertained the amount of coal per square foot of grate surface per hour that should be consumed. Such a man studied the manipulation of his dampers, the regulation of air to his furnaces, the cleaning of his fires, the working of his feed pumps and injectors, and had an intelligent idea of the proper character of his flue gases.

I have been informed that much of the smoke and consequent waste of fuel along our reef is due to the fact that the boiler power at many mines is inadequate, thus necessitating the forcing of combustion. It surely should not be a difficult matter to arrange a system by which firemen should receive a bonus upon the value of fuel saved by their care and intelligence. If such was done, the stoker would be careful to see that bad coal was not supplied to

his employer by interested colliery owners. But, better still, I submit that our Chamber of Mines or other interested body, should follow the example of the Prussian Government, who, in 1902, arranged for a course of instruction for stokers, and ear-marked £2000 per annum for the purpose. The far-seeing and scientific promoter of the measure declared that the Government was alive to the fact that to compete successfully with other nations in certain manufactures it was necessary to reduce the cost of production. He proved conclusively that serious waste was taking place through unscientific and careless stoking, and secured the sympathy, confidence, and assistance of the Government, as I have stated above.

The Hamburg Smoke Abatement Society is a voluntary association of steam-users, and has been in existence about three years. The Society is controlled by a committee, and the technical work is managed by a permanent expert staff. The working expenses are obtained, firstly, from its members' subscriptions; secondly, from payment for special work done for its members; and, thirdly, from payments by outsiders for research work or advice. The membership at present is about 150, with 420 Boilers under their supervision.

The declared objects of the Society, as set forth in its rules, are the attainment of the highest possible efficiency from heating and boiler plants with the least possible smoke. With this end in view, regular examinations are made of the plants of members and their methods of working. The education and control of firemen is undertaken, and tests are made of fuel and appliances. Reports and results are then circulated amongst members. With a view to carrying out some special steam-raising trials, a central Model Boiler installation was installed in Hamburg in 1904, and the results of the research trials are circulated among members in due course. Manufacturers and fuel users generally have been taught that proper combustion of fuel produces economy, and they were advised that the first step was to provide a body of trained stokers. To do that they must be selected and taught in a uniform, practical, and scientific manner by competent engineer instructors. Now, here is an opportunity for us, as the leading scientific Society of South Africa, to justify our existence by promoting this branch of science. I am sure a ready and liberal response would be made by our Chamber of Mines, to any reasonable proposal that may be made to them. Itinerant courses of instruction could be arranged at different centres along the reef, and firemen instructors could be appointed to give the necessary lessons at some fixed centre.

A few furnaces of modern design might be provided to demonstrate their capabilities, and competitions might be arranged between boiler-makers and between firemen, which should place the directors of companies in possession of statistics that should tend to reduce the working costs of our mining, milling, and reduction generally, as well as check a danger to the comfort and health of our community that, in my opinion, is already being felt by those who think of

other things besides the mercenary side of life. In the course of time, employers would naturally give the preference to stokers who could show certificates of having been trained by the body I suggest, and, having secured a reliable body of men, could generate a healthy emulation by offering bonuses to working staffs according to the reduction of the annual coal bill.

Having attended the annual congress of the Royal Sanitary Institute at Glasgow in 1905, the Lord Provost, Sir John Ure Primrose, was good enough to enlighten me upon the work he and other enthusiasts were doing in Glasgow to reduce the smoke nuisance and costs of working, and at the same time he assured me that his researches had proved so successful that he was having his whole installations and staff re-modelled, thus affording the public a practical proof of what can be done in justifying a firm insistence on the part of the authorities of his example being followed.

39—IRRIGATION AND INTER-COLONIAL CO-OPERATION.

By W. L. Strange, M.Inst.C.E., Director of Irrigation, Transvaal.

1. Introductory.

It may be taken for granted that most persons who have lived in South Africa, and that all who have made their homes in the sub-continent, desire her prosperity. The far-seeing leaders of men, who have been and who are still with us, have ever held that that prosperity can best be assured by co-operation which will weld her Colonies into one united whole, and fit her to take a prominent place in that still greater combination of varied countries with diverse races, but with one common centre, to which we give the proud title of Empire. The engineer, who, of all professional men, has had the leading share in making the Empire possible—by improving communications, by developing even its most distant possessions, and by increasing the facilities for civilisation—may well feel that he can help forward the good work in South Africa. Each branch of engineering has its sphere of usefulness, and can aid its numerous other branches, so that a bare enumeration of the important matters in which the profession as a whole has played, and will play, a part in ensuring the progress of the Empire, would take up much space. The author would therefore confine himself to that branch of engineering—irrigation—with which he has been connected throughout his professional career. He proposes shortly to describe the necessity that exists for irrigation; how irrigation has been developed in other countries; the material advantages which can be secured by it in South Africa; the objections raised to it and the answers to them; and how it will serve to weld together the dominant races in the sub-continent. Thereafter, he will discuss briefly the special utility of each of the main classes of irrigation works, and, finally, will deal with the way in which irrigation can best be developed by inter-colonial co-operation, to the mutual advantage of the different Colonies. His experience of South Africa has been limited to three years' service in the Transvaal, but he thinks that the conditions in the other Colonies are sufficiently similar to those which obtain in it, as to make general observations applicable to all. He feels that his remarks could not be addressed more fitly to any other Association than that which has for its object the advancement of science in South Africa, nor in any other place than Kimberley, where the three principal Colonies of the sub-continent may be said to meet.

2. The Necessity for Irrigation.

In all tropical and sub-tropical countries where the rains are not regular and seasonable, irrigation is found to be a necessity. There is no reason why the case should be different in South Africa, where the rainfall on most of the area suitable for occupation by

white men is more or less precarious. Even when it is abundant there, a large portion falls in violent storms, of which the resulting flow rapidly runs off the ground and goes to waste, while frequently another large portion falls at unseasonable periods, and is evaporated or descends deep into the absorbent soil.

The only certainty the farmer has is that during four months of the year a very small amount of rain falls, which is speedily evaporated or absorbed, and for another four months practically none is precipitated. The general conditions are that when water is most wanted it is least available, and that the most valuable crops cannot be grown without artificial watering. During the period of good rainfall the cultivator has, moreover, to contend with special difficulties, such as hailstorms and locusts, which are absent during the rest of the year. So much is he handicapped by these conditions that in the south-western and central divisions of the Transvaal a fair crop is expected only once in five years; in its south-western division many experienced farmers have given up ploughing as a waste of money. It is the opinion of practically all farmers long resident in the Colony that without irrigation they cannot be successful with their crops. This is not a newly-formed idea, for, from the time of the earliest settlements, the riparian farms were always considered the most valuable, and were occupied first, the non-riparian farms being taken up merely as subsidiary to them for cattle grazing, etc. As evidence that the same value is still attached to water may be quoted the facts that its availability is always brought forward prominently at all sales of lands possessing it, and that irrigators are most tenacious of their rights to water. As cultivation increases, the existing natural sources of supply will not suffice for it, and this has already proved to be the case on streams where irrigation has been developed to a considerable extent.

3. IRRIGATION IN OTHER COUNTRIES.

The following figures will give some idea of the extent of irrigation in other countries:—

		Acres.
India (average about 1901).	State Works ...	18,588,000
	Private Works...	25,510,000
	Total ...	44,098,000
Egypt (1)	... ...	5,750,000
United States of America (2)	.. ...	7,600,000
Italy (2)	... ...	4,700,000
Spain (2)	... ...	2,800,000
France (2)	... ...	400,000

In India, it is comparatively of recent date since the British Government undertook irrigation on a large scale. By 1902-03 Government had expended about £28,500,000 on works for which capital accounts are kept, and were spending at the rate of about

(1). "Egyptian Irrigation," by Sir W. Willcocks (Spon, London, 1899).
(2). "Irrigation Engineering," by H. M. Wilson (Wiley, New York, 1903).

£2,000,000 a year on all classes of irrigation. That year the net revenue return on the first-named works was nearly 7 per cent., and the value of the crops matured by their means was estimated at about 88 per cent. of their total cost. The Government of India in 1901 appointed an influential Irrigation Commission to tour all over the empire to ascertain how irrigation could be developed, and this Commission recommended a further capital expenditure of not less than £29,000,000 on new works for the irrigation of 6,500,000 acres. The private works in India consist of wells and small channels and reservoirs.

In Egypt, practically the entire financial position depends upon irrigation. The British engineers employed in its development have raised that country in a comparatively short time from poverty to affluence. It is common knowledge that large works have been constructed there within the last few years. Here, again, investigations have recently been carried out for greatly increased irrigation development, both in Egypt and in the Soudan, upon which it is estimated £22,000,000 can be spent. * The gross yield of the produce from irrigated land in Egypt is estimated at £7 an acre.

In America, irrigation is being extensively developed, principally in the Western States, which, like many parts of South Africa, are arid. This subject there engages the attention of a highly scientific staff, and the result of its work has been to enable the country to export agricultural produce in large amount, despite the high cost of labour.

Mr. Hitchcock says:—† "There is no one question now before the people of the United States of greater importance than the conservation of the water supply and the reclamation of the arid lands of the West, and their settlement by men who will actually build homes and create communities."

In Canada, with a climate much more rigorous than that of South Africa, irrigation is successfully practised, and, recently, the Canadian Pacific Railway Authorities have been furthering new schemes which will bring about 1,000,000 acres under water. Government has given that Railway a large block of land for this purpose, one-quarter of which will be irrigated; already 500,000 acres of this block have been sold.

In the dry parts of old countries of Europe, such as Italy, Spain, and France, which all have colder climates than South Africa, irrigation has been found a necessity for agricultural development, and many fine works have recently been constructed.

Coming to South Africa itself, Cape Colony is inaugurating a more scientific and extensive irrigation policy, Natal has just constructed the Winterton irrigation scheme, the Transvaal has established an irrigation department, and the Orange River Colony, with its limited means, has been starting irrigation schemes as relief works.

* Sir William Garstin's Report on the Upper Nile, Cairo, 1904.
† "Irrigation in the United States," by F. H. Newell.

From the above short account, it may be seen that, although irrigation has attained its greatest development in tropical countries, the white man, in arid countries like parts of South Africa, has found it a necessity, and is rapidly increasing the irrigated area. It would be remarkable if in South Africa alone, where water is badly wanted, where the price of agricultural produce is probably higher than it is anywhere else, and where so great a proportion of it is imported, that irrigation should not be a success.

In some countries irrigation is a vital necessity; in others, it is eminently desirable; while in others it is not wanted. The Colonies of South Africa fall under the second description, and in them irrigation is much appreciated. They can accept with confidence as a guide the experience of similarly situated countries, such as the Western States of America, where irrigation has been a great success and is rapidly extending. It is not necessary that the similitude should be exact; the underlying general principles can be followed, the general results intelligently applied, and development more quickly obtained by avoiding the mistakes which have elsewhere been committed through inexperience.

4. ADVANTAGES OF IRRIGATION.

The following may be stated as some of the advantages of irrigation:—

(a) Without it the success of agriculture cannot be assured in the arid parts of South Africa.

(b) It will permit more stock to be raised, as by it fodder (such as oat hay) can be produced at a cheaper rate than it can be imported, owing to its bulky nature; moreover, green fodder, such as lucerne, cannot be imported in a succulent state. In its turn, stock raising will help irrigation by the manure produced by it.

(c) It will cheapen the cost of living by reducing the amount of imported produce.

(d) It will afford congenial employment to the rural population, which has never taken to mining.

(e) Intense cultivation will mitigate the effects of the present law of inheritance, by which estates are being gradually subdivided into otherwise unremunerative small holdings. It will thus tend to prevent the formation of a poor white population.

(f) It will permit of the formation of settlements with common aims and objects, which will lead to the fusion of the white races.

(g) Irrigation in India and Egypt brings in to the State a large return on the expenditure incurred upon it. It should, at least, be self-supporting in this country, and will probably be directly remunerative.

(h) In India and Egypt it is recognised that the indirect advantages of irrigation in increasing the wealth of agriculturists conduce greatly to the advantage of the State, and thus justify the

construction of works not directly remunerative in themselves. The same will hold good here, as an increase in the purchasing power of a large section of the community must benefit the rest of it.

(j) Agriculture (and this includes irrigation) is the most permanent of all industries; it is advantageous to the country as a whole to foster it, especially while its revenue is increased by the profits from mining which may eventually diminish.

(k) Irrigation will, in favourable circumstances, permit of two crops being grown annually; that raised in the cold season will not be liable to damage by floods, hailstorms and locusts, and will thus be practically secure.

(l) Irrigation works can be constructed almost entirely by local labour, as but an insignificant part of them will have to be imported. Their construction will therefore benefit the resident labouring community. In this respect they compare most favourably with railways.

5. ALLEGED NON-REQUIREMENT OF IRRIGATION.

By some it has been stated that irrigation is not wanted, because :—

(a) The population is too small to require it.

(b) It will be cheaper to import produce than to grow it.

(c) Owing to the high price of labour, it will be impossible to export surplus produce.

Generally, it may be said that such objections are raised by persons who have not resided long in the country, or who have not had experience of the success of irrigation in other countries. It is surely more reasonable to attach greater importance to the opinions of those who have been born and bred in the country, and of those who have seen what irrigation has done elsewhere. Both of these latter classes are greatly in favour of developing South Africa by means of irrigation. (*Vide* "Agriculture Within the Empire," pp. 138-140).

Theory is all very well, but it is not always reliable. A few years ago it was said that plantations would not be successful near Johannesburg. The Sachsenwald one is now a proof of the fallacy of this idea. It is far better to rely upon the results of experience, even if that has been obtained in other countries.

The following remarks are made as to the objections stated above :—

(a) The total population of the Transvaal by the last census * was 1,268,716, and the cultivated area in 1902-03 was estimated at 391,000 † acres, or only 0.31 acre per head, which is quite insufficient for the support of the inhabitants. Of this area, by far the largest proportion is devoted to the growth of mealies—an

* Transvaal Census Report, 1904.

† Transvaal Administration Report for 1903.

unirrigated crop. In addition, it is estimated that there are 6,667,000 * acres available for cultivation. Everyone anticipates that mining and other industries will rapidly expand, immigration is taking place, and it is well known that the Dutch and Native inhabitants are prolific; from all these causes the population should largely increase. Naturally, the best lands have been put under cultivation first, and it is uncertain if agriculture, unaided by irrigation, will be able to keep pace with the increase of the population.

(b) The customs returns for the year ending 30th June, 1905 † (*Vide* Appendix 1), show that over £2,000,000 of agricultural produce, which could be grown under irrigation, was imported. This is evidence that much lee-way has to be made up, and the increase of population will for long be in advance of the increase of irrigation.

(c) It is doubtful if agricultural labour in the Transvaal, after conditions have become more settled, will be as high-priced as it is in purely white Colonies, for here cheap native labour is procurable, and will probably be then available for agriculture. It is the experience of other Colonies and of America that, even with their high rates of labour, they are able, owing to the favourable natural conditions of climate and soil, to export agricultural produce to other countries with cheaper labour.

Irrigation in South Africa will permit of the growth of lucerne, oat hay, wheat and other crops, which can be consumed locally, and of fruit, tobacco and semi-tropical produce, which can be exported at a profit. It is well known that America, by greatly developing its iron industry, has been able to compete with English trade by exporting its surplus production at cheaper rates than are obtained in its own market, and South Africa should be able to adopt the same principle in regard to its agricultural products.

6. POLITICAL CONSIDERATIONS.

Politics are not in the province of the engineer, but as in this country they pervade everything, so they affect the question of irrigation. In all countries there is a conflict of interests between town and country. Here this is intensified by the fact that the former is associated with the British and with capital, and the latter with the Dutch and with poverty. All prominent politicians state their earnest desire to fuse the two races into one; in no better way can this be done than by developing agriculture (and with it irrigation), so as to convince the rural population that their interests are not being sacrificed to the requirements of the urban portion of the community.

The Dutch population has not taken, and probably will not take, to mining, whereas the pursuit of agriculture is peculiarly

* Transvaal Administration Report for 1903.

† Report of the Transvaal Agricultural Department, 1904-5.

congenial to it. A reasonable amount of State assistance in the development of agriculture will be most acceptable to it, and in turn will benefit the mining community by reducing the cost of living. One of the best forms of such assistance is the construction of irrigation works, the capital cost of which is beyond the means of private persons. At the same time, as such expenditure should be productive, its disbursement will not tend to pauperise the people. The Dutch are a prolific race, and unless increased means of agriculture, such as irrigation affords, are placed at their disposal, it is almost certain that the existing poor white population will be increased. This has always been recognised in South Africa as an element of danger to the State, and particularly so because the larger proportion of the population is a coloured one. Before the war there was special legislation on this subject; even now, cases have occurred in which poor Boers have ploughed lands for Kaffirs.

Without irrigation it will be practically impossible to establish settlements of British and Dutch. To plant British settlers out at long distances from each other on separate farms will be of little use in preserving their characteristics, the retention of which is so desirable.

These are the broad political considerations which justify the extension of irrigation, as required by the development of the country. It is, however, sincerely to be hoped that irrigation will not be prostituted to party considerations, for, if it is, experience has shown that its progress will inevitably be retarded, and its benefits diminished.

7. THE MAIN CLASSES OF IRRIGATION WORKS.

In regard to their size, irrigation works may be thus classified :—

Small works—to be constructed by private enterprise;

Medium-sized works—to be carried out by Water Boards and Associations of Farmers;

Large works—to be executed by individual Colonies under State management;

First-class works—to be prosecuted by Inter-Colonial State agency.

These classes of works are not competitive with each other; they are, in fact, complementary to each other. Each of them has its own particular use, and is peculiarly adapted to the development of areas which cannot suitably be dealt with by the others. The advantages and disadvantages of each class will now be described shortly.

8. SMALL WORKS.

These, as a rule, will be small storage reservoirs, and furrows led from springs and small perennial or semi-perennial streams.

The advantages of such works are that they will utilise small catchments and small natural physical features, and that they will provide for the irrigation of small isolated areas, which could not otherwise be supplied with water. They can be made cheaply by means of local labour, and, as they will not require high-class engineering, they can be carried out by farmers, with, if necessary, a little professional advice and some assistance from the State by means of loans. They are eminently suited for private effort, and they can best be constructed by individual farmers, who are the best judges of local conditions and requirements. Their construction will develop enterprise, and their maintenance and utilisation will encourage independence, as they will be under the sole control of their owners. By their means farmers will be enabled to grow high-priced crops, to practise intense cultivation, and, generally, to develop their farms.

The disadvantages of such works are that their cost per unit of supply will usually be excessive, their supply may fail in bad years, and, even in good years, will in many cases prove insufficient to last until the end of the dry season, when it is most useful for starting crops.

It would be impossible for the State to undertake such works with economy in construction or maintenance, or to administer and collect revenue from them. All that it can do is to assist farmers by loans and by professional advice, and thus to lead to the establishment of numerous works all over the country, so as sensibly to increase its productive powers.

9. MEDIUM-SIZED WORKS.

These will generally consist of medium-sized storage reservoirs and furrows led from the smaller rivers; of works, for the drainage of vleis and swamps, and the reclamation of fertile bottom lands; for the opening up of the sources of springs and the improvement of the channels of the smaller rivers; and for the linking up of numerous furrows where they exist, so as to utilise the available supply more economically. Such works will improve the agricultural conditions of a district.

The advantages and disadvantages of these works will be similar to those described for small works, but generally their material advantages will be greater, and their disadvantages will be less, than those of that class. They will have the further advantage of inducing co-operation without much surrender of individuality, seeing that the schemes will be managed by the popular vote of those benefited by them.

As far as investigation has gone in the Transvaal, there are not many suitable sites for medium-sized reservoirs. This is due to the fact that on the high and middle veld the slopes of the smaller rivers and of the country through which they run are very steep, being on the highly elevated crest of the sub-continent, and also to the valleys being restricted in width, and having few cross ridges suitable for the location of dams and waste weirs.

10. LARGE WORKS.

These will usually take the form of large storage reservoirs, constructed on streams with fairly large catchments, and of moderate-sized canals led from rivers, with fairly good perennial flow. The expense of the construction of such works will generally be so great that they will be out of the reach of Water Boards, as it is not likely that the State will feel justified in advancing to them loans of the necessary magnitude. Their construction will also involve high professional skill, and their maintenance, considerable administrative ability, both of which can best be supplied by the State.

The direct financial returns from such works will probably for many years be small, as development by irrigation is slow, and, even when full development is attained, will not be so great as to tempt commercial enterprise to embark on such schemes. The State can, however, profitably undertake them; it can afford to wait for the complete development of its projects, and it can be content with moderate direct returns, which will be accompanied by indirect returns, from which it will also reap benefit. Moreover, for these reasons the State can be a more liberal owner than can a financial corporation, and the irrigators will thus gain increased advantage by being placed under an administration which has for its main object, not high profits, but the general advancement and prosperity of the agriculturist, which will lead to those of the whole community. The State is justified in looking upon sound irrigation schemes as public works for the development of its territories, just as much as are roads and public buildings, from which no direct return is received.

The advantages of large, compared with small, storage reservoirs are their cheaper rate of storage; they are the only ones which can take full advantage of the run-off from large catchments. They are also the only ones economical on them, seeing that, for any given catchment, the size and cost of the waste weir are independent of those of the dam embankment, while the cost of the outlet and the puddle trench do not vary greatly with the general scale of the project. The mean depth of large reservoirs is much greater than that of small ones, and thus in the former the proportionate loss by evaporation is much less than it is in the latter. This consideration is of much importance in South Africa, where the quantity of such loss will probably be equivalent to an amount of storage equal to the mean area of a reservoir multiplied by a depth of 4 feet. Further, a small reservoir on a large catchment will silt up much more rapidly than a large one on it, for both will intercept very nearly the same amount of deposit.

The advantages of large canals from large rivers are that these works also utilise more fully the natural asset of water available, and that these rivers have a greater and more certain perennial flow, especially in bad seasons, than have small rivers. As the larger rivers naturally have considerable floods and usually run in deep troughs, to secure immunity from damage, the canals from them must be rapidly led out of the flood margin and on to the country. Thus,

small canals taken out from them will require headworks practically as expensive as those of large ones, and will therefore *pro rata*, be more expensive, while their benefit to the country will be much less. Moreover, a large canal can carry water more economically than a small one, and can more rapidly gain command of irrigable land.

In some cases it will be possible to construct the canal first, and thereafter to provide storage for it when this development becomes necessary; such procedure in gradual stages will generally be the most advantageous one to adopt, as irrigation is usually a plant of slow growth.

Taking both large reservoirs and large canals together, their advantages are that they better utilise the natural assets of more certain supply and of the flatter slopes of the country which characterise large catchments. The larger rivers have the further great advantage that on them there are fewer established riparian rights, so that more comprehensive schemes can be established on them, with less interference with such rights.

It is, moreover, an irrigation maxim that a scheme must be on a scale having a direct relation to that of its source of supply, or its cost will be unnecessarily great and its utility will be needlessly diminished.

Compared with small schemes, the cost of both the construction and maintenance of fair-sized schemes per acre irrigated will generally be considerably less, and the charge for water-supply can therefore be reduced. It is thus more economical for the State to undertake such projects, and more beneficial to the country as a whole to have large areas irrigated.

The disadvantages of large works may be said to be their great cost, the uncertainty of getting all irrigable land under them occupied, and the chance of constructional failure. On the other hand, contrary fears have been entertained of their too great success, whereby the market will be swamped, and small farmers on dry lands will be unable to compete with irrigators under them. The answer to the first set of objections is that they should not carry weight in a progressive country if the programme of construction is properly adapted to its requirements, seeing that there is the experience of many other countries available as a guide, and the successful completion of numerous schemes in them as an encouragement. The replies to the second set are that even the enthusiast in irrigation in making his proposals will surely be restrained by reason, and will not suggest so many schemes as will wreck the financial prospects of all, and that, as explained above, there is in this country ample scope for the successful existence, side by side, of schemes of different magnitude and for different classes of agriculture.

11. FIRST-CLASS WORKS.

So much has just been written about the class of "large works" that but little remains to be noted concerning "first-class works."

Their advantages will be still greater, as these works will be constructed only on the large rivers which have the most assured supply, and are the largest irrigation asset of the country; these rivers cannot, however, be properly utilised, except by schemes of considerable magnitude. Moreover, these rivers traverse the parts of the country with the most suitable physical conditions, not only for irrigation, but for the all-important matter of easy communications. The larger an irrigation work, the more likely is it to be a financial success, for the concentration of irrigation will enable cultivation to be carried on in the cheapest manner by means of the most modern agricultural implements, and the water supply to be utilised most economically. The construction of such a work will enable central depôts to be established for crop, dairy and meat produce, such as manufactories, creameries and cold storages. The farmers under it can thus combine, and, without the help and cost of middlemen, can capture and retain the home market, now so largely supplied from oversea. The exporting countries are, moreover, so geographically remote, that competition with them should not be difficult if it is arranged for by proper scientific methods, of which those very countries have shown the value. The magnitude of the irrigation operations will not only justify, but will demand, the construction of good roads and branch railways that will furnish the means of cheap transport, the lack of which at present is the principal factor permitting oversea competition to be successful.

As an example of the value of a first-class work, the Chenáb Canal * in the Punjab, the largest recent project in India, may be quoted. This canal is taken out (*Vide* General Plan) on the left bank of the Chenáb, the second principal tributary of the Indus, and irrigates the area between the Chenáb and the Rávi, which previously was a very sparsely inhabited and desert tract of Crown land. It was originally completed in 1887 as an inundation canal, i.e., one without a weir, and entirely dependent for the amount of its supply upon the fluctuating level of the river. Such a canal did not take full advantage of the amount of water available, and, accordingly, the construction of a weir, with regulating works, was sanctioned in 1888, and the remodelling of the canal itself, in 1892. At its head it is 250 feet wide and 10.8 feet deep, and it carries 10.800 cubic feet per second; in other words, its discharge is as large as that of the Thames at Twickenham in flood. The weir was completed early in 1892, and since then the expansion of irrigation has been extremely rapid, as the following table will show:—

	Acres irrigated.
1892-93	157,197
1897-98	810,000
1902-03	1,829,169

Eventually, it is anticipated that it will irrigate 2,500,000 acres. Its capital cost up to 1902-03 was about £1,830,000, and the net

* Recent developments in Punjab Irrigation, by Sidney Preston, C.I.E.—"Journal of the Society of Arts," Vol. L., No. 2,586, May 30th, 1902.

GENERAL PLAN OF CHENÁB CANAL

SCALE 37½ MILES = 1 INCH.

return on this expenditure in that year was 21.3 per cent. The population has increased from a few thousand nomads, possessing only camels, goats, etc., to 792,000 agricultural colonists (1901 Census) inhabiting towns and villages, and, for India, in most affluent circumstances. Early in the history of the scheme a railway was seen to be an absolute necessity, but, unfortunately, some years elapsed before funds were available for its construction. The colonisation scheme at first nearly failed, owing to the impossibility without the railway of transporting the immense quantity of produce, and of realising its value and thus paying the Government assessment. By means of this and other large Punjab canals the export trade of Karachi has increased enormously, and last year, for the first time on record, the export of wheat from India to England exceeded that from any other country.

12. INTER-COLONIAL IRRIGATION SCHEMES.

The two largest rivers of the most thickly populated part of South Africa are the Vaal, forming the boundary between the Transvaal and the Orange River Colony, and the Orange River, which for a considerable length of its upper course divides the Orange River Colony from Cape Colony. While nature has thus made them lines of separation, man, by utilising them for irrigation, can constitute them into bonds of union. By the construction of masonry weirs and dams across these rivers, reservoirs common to the neighbouring Colonies can be formed, and from them canals can be led on each side for the irrigation of their respective territories. The natural conditions being equal, a single canal supplied by a storage reservoir is nearly 1½ times as expensive per acre irrigated as two canals led out from it on the two banks of the impounded river. The financial advantage of co-operation is thus great, and a further benefit of this nature is that the schemes will be constructed from the revenues of two Colonies, instead of one, and will thus involve a smaller demand on the resources of each.

Sir William Willcocks, in the middle of page 41 of his "Report on Irrigation in South Africa," suggests that the waters of the Vaal should be reserved for the Transvaal and the Orange River Colony, while those of the Orange River would be available for Cape Colony. How far the upper course of the Orange River can be utilised by the two Colonies which it divides is not known to the author. The development of inter-colonial irrigation from the Vaal has, however, formed the subject of an extensive reconnaissance of the river, over 500 miles long, by engineers deputed to it from the Transvaal and the Orange River Colony. Their investigations have proved that four schemes serving both Colonies are practicable and desirable. A further examination of the lower part of the Vaal by engineers of the Transvaal and Cape Colony has shown that probably the best scheme on the river is available there for irrigation in these two Colonies, and, possibly, also in the Orange River Colony. The

approximate figures for these projects are given in the following table :—

Particulars.	Unit.	Klip River.	Koppiesfontein.	Lindiques Falls.	Coalmine Drift.	Christiana and Hartz River.
(a) Excluding increased value of Land rendered Irrigable.						
1. Total estimated cost of Project ...	£	283,000	945,000	285,000	515,000	1,144,000
2. Full Supply Storage	Mill Cft.	4,165·82	5,545·72	2,403·73	2,603·96	11,451·00
3. Estimated rate of Storage ...	£ per Mill Cft.	33·36	38·50	47·80	100·30	31·44
4. Area Irrigable ...	Acres.	21,600	60,000	18,000	26,000	90,000
5. Cost per acre Irrigable (1) ÷ (4) ...	£	13·10	15·70	15·83	19·80	12·71
6. Estimated net Revenue ...	£	16,200	48,000	18,900	32,500	67,500
7. Percentage Return of (6) on (1) ...	p.c.	5·72	5·08	6·63	6·31	5·90
(b) Including increased value of Land rendered Irrigable.						
8. Estimated Increased value of land @ £10 per acre ...	£	216,000	600,000	270,000	390,000	900,000
				at £15 per acre.		
9. Net estimated cost of Project (1) – (8)	£	67,000	345,000	15,000	125,000	244,000
10. Percentage Return of (6) on (9) ...	p.c.	24·18	13·90	126·00	31·00	27·66

It will be seen from this table that, although the schemes proposed are of fair size, none are of heroic dimensions, and, compared with the Chenáb Canal, are on a moderate scale. There are, however, but very few other projects in the Transvaal from each of which even as much as 20,000 acres can be irrigated, and that with less certainty of supply and at greater cost than those from the Vaal.

The Orange River Colony has drawn up a very large scheme at Parys for the irrigation of some 300,000 acres at a cost of about £3,000,000. It is possible that this scheme could be extended

at a total cost of £5,000,000 to irrigate an additional 100,000 acres in the Transvaal. Unfortunately, it is on far too ambitious a scale for the present requirements of the two Colonies, and it cannot be commenced on a smaller one and be subsequently enlarged. The time may come, however, when it will be wanted, and it is as well that it should not be lost sight of.

Schemes of the magnitude described above may have the advantage of rendering the climate in the neighbourhood more humid, and, if this proves to be the case, their benefit will extend beyond their own immediate limits.

13. INTER-COLONIAL CO-OPERATION.

Irrigation schemes of all sizes have now been discussed broadly, and chiefly from the engineering point of view. It has been pointed out that each class of scheme has its own special utility, and that, if any scheme fulfils the main requirements of feasibility, suitability, desirability, and moderate financial success, it can be undertaken with confidence. It is, perhaps, needless to add that each project should be carefully and fully investigated before it is started, so as to avoid the commission of costly mistakes. It now remains to make a few general observations on the main subject of this paper.

Although the Colonies are at present only in their preliminary stage of development, difficulties have arisen in regard to water questions connected with the Vaal, owing to the deficiency of its supply at the end of the fair season. During each of the last three years its flow at Christiana has practically ceased for two or three months, and is likely to fail this year for a considerably longer period. The restriction of irrigation from its upper tributaries has even been suggested, so as then to secure supply to the lower riparian towns in Cape Colony, including Kimberley. It is hardly necessary to point out that, even if this were practicable, it would be a retrograde step to take, and it would introduce inter-colonial friction instead of co-operation. It is, however, not practicable, as the laws of each Colony run only within its boundaries, and the upper Colony would certainly never consent to being deprived of its natural resources for the benefit of the lower Colony. Considering the case of two Colonies separated by a river, the best way, theoretically, is to divide its flow between them in proportion to their contributions to its discharge. Such discharge depends upon the extent of the catchment area, the nature of the country, and the intensity and amount of the rainfall. To determine the discharge to which each Colony has a fair claim would take many years of observation, and, even when determined from the results ascertained, the proportion arrived at might, with the variation of rainfall in a subsequent season, then prove an unfair one. Owing to the great fluctuation in the flow of even these large rivers, to depend upon them in their natural condition will frequently lead to difficulty. The obvious remedy is to reduce these fluctuations artificially by means of storage weirs and dams, whereby a definite amount of supply can be

obtained in all years, and can be divided in accordance with settled arrangements, effected jointly by the Colonies concerned. Thus all chance of inter-colonial friction will be prevented by means of inter-colonial co-operation, which will establish a community of interests that must inevitably form a bond of union. An excellent instance of the benefits of such co-operation is the appointment of the Inter-Colonial Irrigation Commission, upon which are representatives of the Transvaal and Orange River Colony. This Commission is enquiring into the best way in which the existing irrigation law can be amended so as to meet the altered conditions which now exist. Without a new law suitable to those conditions, the proper development of irrigation will be impossible.

The tendency in new countries (and one which, unless it is extirpated at the outset, may be intensified as time goes on) is to consider first, individual, rather than collective requirements, and to look at everything from a narrow rather than from a broad point of view. Fortunately, South Africa has already furnished several examples of the advantage of co-operation. In State affairs there are the Customs Union, and the joint management of railways in the Transvaal and Orange River Colonies, which, it is hoped, will be extended to Cape Colony. In commercial affairs there are the gold fields of the Rand, which, under the most adverse natural conditions, produce the largest output in the world, and the Kimberley Diamond Mines, which, from a congeries of petty individual effort, have developed into the most productive combination known. By this co-operation scientific development has enormously advanced, and, by a similar one, it is probable that irrigation engineering will equally benefit for the good of agriculture all over the Colonies. Agriculture is the oldest and most permanent industry in the world, and is practised by the large bulk of its inhabitants. Anything that tends to its development and renders it more certain will benefit the whole population, and nothing can ensure this better in South Africa than the construction of large irrigation schemes on well-considered and sound lines.

Appendix I.

STATEMENT OF IMPORTS OF AGRICULTURAL PRODUCTS INTO THE TRANSVAAL.

For the Year ending 30th June, 1905.

(*Report of Agricultural Department, 1904-05, page 44.*)

	Quantity. lbs.	Value. £
CORN AND GRAIN—		
Beans and Peas	4,421,947	18,592
Chaff	577,166	830
Dholl	442,193	1,689
Kaffir Corn	5,697,807	17,464
Lucerne and Fodder	36,493,257	81,385
Manna...	4,237	37
Mealies	88,645,632	194,324
Oathay	43,129,970	94,166
Oats	30,483,895	77,751
Wheat	2,428,721	11,152
FLOUR AND MEAL—		
Wheaten	89,169,764	432,306
Other Kinds	7,498,945	24,335
VEGETABLES (FRESH)—		
Onions	4,957,401	20,537
Potatoes	14,616,797	49,897
Preserved	2,193,818	24,401
Total ...		£1,048,866
Preserved Meat...	6,479,517	186,984
Fresh Meat and Game	62,473,722	794,229
Grand Total		£2,030,079

NOTE.—In addition to these, considerable quantities of butter, milk, cheese, margarine, eggs, bacon and ham were imported.—W.L.S.).

40—POLYCYCLIC SYSTEMS OF CURRENT DISTRIBUTION.

By H. Bohle, M.V.D.E., M.I.E.E., Professor of Electro-technics at South African College.

When electrical energy has to be transmitted over great distances or distributed over large areas, high pressure alternating current is used in order to limit the expenditure in copper. If the energy is used solely for power purposes, a low frequency current is preferable, since the construction of motors and rotary converters is more rational for periodicities below 40 than for those above it. For pure lighting networks, however, the frequency should be 50 or more, as arc lamps do not burn satisfactorily on a lower frequency.

For mixed lighting and power plants, we usually effect a compromise, i.e., we choose a frequency of about 50, which is ideal neither for lighting nor for power.

As regards the number of phases, it is well known that polyphase rotaries and motors are superior in starting and running qualities than single phase machines, and less expensive to manufacture. The pressure regulation, however, is simpler for single phase than for polyphase currents. One is further justified in allowing a greater pressure drop in power than in lighting circuits, the drop being much less noticeable in the former case than in the latter. Consequently, if we have a mixed lighting and power network, the allowable drop is soon reached, and the expenditure in copper is larger than for a pure power plant of the same total magnitude.

It is further necessary, on account of the low voltage of the present day incandescent lamp, to employ a pressure below 300 volts for lighting circuits, while it is allowed to run motors from circuits up to 500 volts. It is therefore obvious that the quantity of copper required for a mixed circuit is greater than for a pure power network of the same magnitude.

The disadvantages of a mixed plant are overcome by having separate plants for lighting and for power purposes; for instance, by employing two phase or three phase currents of 25 periods for power circuits, and single phase current of 60 or more for lighting networks. This, however, increases the capital outlay, and complicates the switching arrangements.

A more rational solution of this intricate problem is found in a system which transmits at the same time currents of different frequencies and phases through the same network.

Suppose we have two sine currents of the frequencies f_1 and f_2, produced by sine E.M.F.s of similar periodicities, then the current of frequency f_1 performs work with the E.M.F. of the same frequency, but not with the E.M.F. of frequency f_2. If one current, say i_1, varies, its E.M.F. will also change, but not the other E.M.F., as long as i_2 remains constant, because the two currents are absolutely

independent. The total power absorbed by the circuit is equal to the sum of the powers of the two currents, i.e.,

$$P = E_1I_1 \cos \phi_1 + E_2I_2 \cos \phi_2,$$

and the copper loss caused by the currents in the resistance R is equal to $(I_1^2 + I_2^2)$ R.

The author believes that the first polycyclic system was due to Dr. F. Bedell, the connections of a three phase single phase system, as invented by him, being shown in Fig. I. Here G_3 and G_1 represent three phase and single phase generators respectively, T_3 and T_1 three and single phase transformers, M_3 a three phase motor, and L a lighting circuit.

Suppose now that the currents of the different phases of G_3 are equal and follow sine laws, then points o_1 and o_2 will be of the same potential, so that a single phase current may be introduced in these points, passing through the varies circuits as if no other currents were present. The direction of the superposed current only is indicated by the arrows.

A single phase current may be superposed not only upon three phase, but also upon two phase or another single phase currents. The latter is then considered a two phase current with phases at 180 degrees, see Fig. 2.

Bedell's system has the disadvantage that the superposed currents are carried by the primary system only, and that, since the circuits of the superposed current are highly inductive, the pressure drop is enormous.

The latter disadvantage may easily be obviated by winding the circuits noninductively for the superposed current without interfering with the induction of the original currents. Consider the choking coil as shown in Fig. 3, and assume that the superposed current enters by b_1 and b_2, leaving at e, while the original current enters at b_1 and leaves at b_2; it is obvious that the inductive action of the superposed current is nil, since the flux caused by one coil is neutralised by that set up by the other on the same limb, whereas the inductive actions of the original currents are added. Such bifilar windings may be given to all kinds of polyphase transformers and generators, as illustrated in Figs. 4 and 5. The former illustrates a three phase transformer, the latter a three phase generator or motor.

Arnold-Bragstad-la Cour, the inventors of this system, have further shown that superposed currents may not only be conducted by means of transformers, but also be induced by them. The principle of this new method consists of the simultaneous transformation and supply of alternating currents of different phases and frequencies into the mains of a distributing network by employing transformers with two kinds of primary and one secondary windings, and by taking off these currents by means of one primary and two secondaries.

In Fig. 6, A represents the primary, B the sub-station. In A, two kinds of currents are generated and transformed, from B, two networks are supplied, the transmission of both currents taking place through the same mains. At the primary station, we have three single phase transformers, with two primary windings—one for the principal three phase, the other for the superposed single phase current—and one secondary winding carrying both currents. The coils of the three phase primary circuit are joined in star form, those of the single phase circuit in series. In this way, we induce both kinds of currents in the secondary winding, and the superposed current is carried along with the three phase currents, its return circuit being formed by the neutral wire.

The receiving, or sub-station, may be constructed in a similar manner, but with one primary and two secondaries. Instead of single phase transformers, we may employ one three phase transformer with a common magnetic return, such as is shown in Fig. 7. The magnetic return is required for the fluxes produced by the superposed single phase currents, which pass through the other three columns in the same direction. The transformer serves at the same time for transforming both kinds of currents, the original three phase current being used for motor, the superposed single phase for lighting circuits.

It is not absolutely necessary to have a special return for the superposed current, as is seen from Fig. 8. The superposed current enters here by the neutral points, and takes its course as follows:—Generator G_1, transformer T_3', busbars BB, transformer T_3'', generator G_1. The transformers transform not only the original, but also the superposed single phase current, and the two sets of mains, S_1 and S_2, serve as going and returning conductors respectively for the superposed current. The separation of the two currents is also illustrated in the same figure; it is effected by means of single phase transformers possessing one primary and two secondary windings.

Fig. 9 shows how four phase and a superposed single phase currents are transmitted over the same lines and separated at the other end. The figure is self-explanatory.

SIMULTANEOUS PRODUCTION AND TRANSFORMATION OF TWO CURRENTS OF DIFFERENT FREQUENCIES.

It is possible not only to set up independent E.M.F.s. of various periodicities in transformers, but we can also produce them in the same generator, for which purpose we require a machine with two independent field systems.

Suppose we require three phase currents of 25 and single phase current of 75 periods per second, and that the combination generator is coupled to a prime mover running at 187.5 revolutions per minute, the number of poles of the field system producing three phase currents must then be equal to 16, that setting up single phase currents 48. If the poles are arranged as shown in Fig. 10, the

E.M.F.s. induced are given by Fig. 11, if fixed as illustrated in Fig. 12, by Fig. 13. In the former case, the resultant E.M.F. has a peaky appearance, and its formfactor is greater than that of curve I.; consequently, the total hysteresis losses are reduced. In the latter case, the resultant E.M.F. curve is flatter than that of I, and the total hysteresis losses are increased. This arrangement has, however, the advantage of producing less strain on the insulation, and this is usually of greater importance than the reduction in the iron losses.

In the systems described so far, we cannot join the consuming devices of both kinds of currents to the same mains, and we require bifilar wound choking coils or motors to separate the currents. In D.R.P. 128406. Arnold-Bragstad-la Cour gives, however, a modification of their original systems, which makes the joining of both kinds of consuming devices to the same mains possible. The connections of such a modified three phase single phase polycyclic system are shown in Fig. 14, in which one main of the distributing network is common to both systems. These are now, however, no longer independent of each other, because the currents of each system have two circuits through which to pass. For all practical purposes, however, the drop caused in one system by large variations of the currents in the other system is negligible. In Fig. 15, both primary and secondary circuits are of the modified type, in Fig. 16 the primary circuits are independent, the secondary modified, and in Fig. 17 both are again of the modified type, for a two phase single phase polycyclic system. The various diagrams are self-explanatory.

DIFFERENCE OF POTENTIAL BETWEEN THE MAINS.

Consider a two phase single phase polycyclic system with both circuits independent, such as is illustrated in Fig. 18. If E_2 be the R.M.S. P.D. between two leads of the two phase system, then—assuming a similar R.M.S. P.D. between conductors a and b of the single phase circuit—the P.D. of the single phase generator must be

$$\frac{E_2}{\sqrt{2}}.$$

The amplitude of the P.D. between wires a and d, or b and c, is

$$\sqrt{2}E_2,$$

if we assume sine waves, but that between a and b will be greater, and will depend upon the position of the two pressure curves relatively to each other. In fact, in the most unfavourable position, see Fig. 11, it is $2E_2$. If the periodicity of one system is an uneven mutiple of that of the other, it is advisable to fix the poles in such a manner

that two positive peaks cannot occur at the same time, as shown in Fig. 13. A similar reduction in the amplitude of the resultant E.M.F. is obtained by making the frequency of one system an even multiple of that of the other, as represented in Fig. 19.

As regards the modified two phase single phase system, it is always advisable to earth the middle point of the winding of the superposed current, as otherwise—through faulty insulation of the two phase winding—we may obtain too high a P.D. between the lighting mains and earth.

PRESSURE DROP IN A POLYCYCLIC SYSTEM.

Consider a two phase single phase system with an independent primary circuit, as shown in Fig. 18, in which the R.M.S. P.D. of the single phase generator is

$$E_1 = \frac{E_2}{\sqrt{2}}.$$

If we assume the same percentage wattloss for both systems, and call the single phase current I_1, the two phase current I_2, and the resistance of one main R, we have

$$\frac{4I_2^2R}{2E_2I_2} \times 100 = \frac{I_1^2R}{E_1I_1} \times 100,$$

or $\frac{2I_2}{E_2} = \frac{I_1}{E_1}$. Now $E_1 = \frac{E_2}{\sqrt{2}}$, hence

$$I_1 = \sqrt{2}I_2, \quad \text{and} \quad E_1I_1 = E_2I_2 = \frac{1}{2}(2E_2I_2),$$

i.e., the power of the superposed current is equal to half the power of the two phase current. It shows, further, that without altering the efficiency of the two phase system, or the R.M.S. P.D. between any two conductors, we can transmit through the same mains 50 per cent. more power with a polycyclic two phase single phase system than with a pure single phase plant. Again, for the same total power, the amount of copper required for a polycyclic system is only

$$\frac{1}{1.5},$$

or 66.7 per cent. of that wanted by an ordinary single phase circuit.

If for a transmission of power the R.M.S. P.D. is given, it is found that with a two phase single phase polycyclic system we can transmit 23 per cent. more power than without a superposed current;

for, as we increase the losses in the four mains 1.5 fold, by superposing a single phase current of half the power, this same total loss would be caused by an increase in the two phase current of a pure two phase system equal to

$$\sqrt{1.5}$$

times the original current. Consequently, we can transmit

$$\frac{1. - \sqrt{1.5}}{1.5} \times 100,$$

or 23 per cent. more power with the polycyclic system.

A three phase single phase system is not so advantageous, and the saving is only about 6 per cent. instead of 23, so that it would seem advisable to convert a three phase current into a two phase current before distribution by means of the well known Scott system. This has been done in Fig. 20. For, since a three phase, three wire system requires a quantity of copper equal to 75 per cent. of that wanted for a single phase plant, all conditions being equal, the saving in material is

$$\left[\sqrt{\frac{75}{66.7}} - 1 \right] 100 = 6\%,$$

assuming that the superposed power is equal to half the three phase power.

ADVANTAGES OF A POLYCYCLIC SYSTEM.

1. The desired frequencies for lighting and power circuits are obtained.

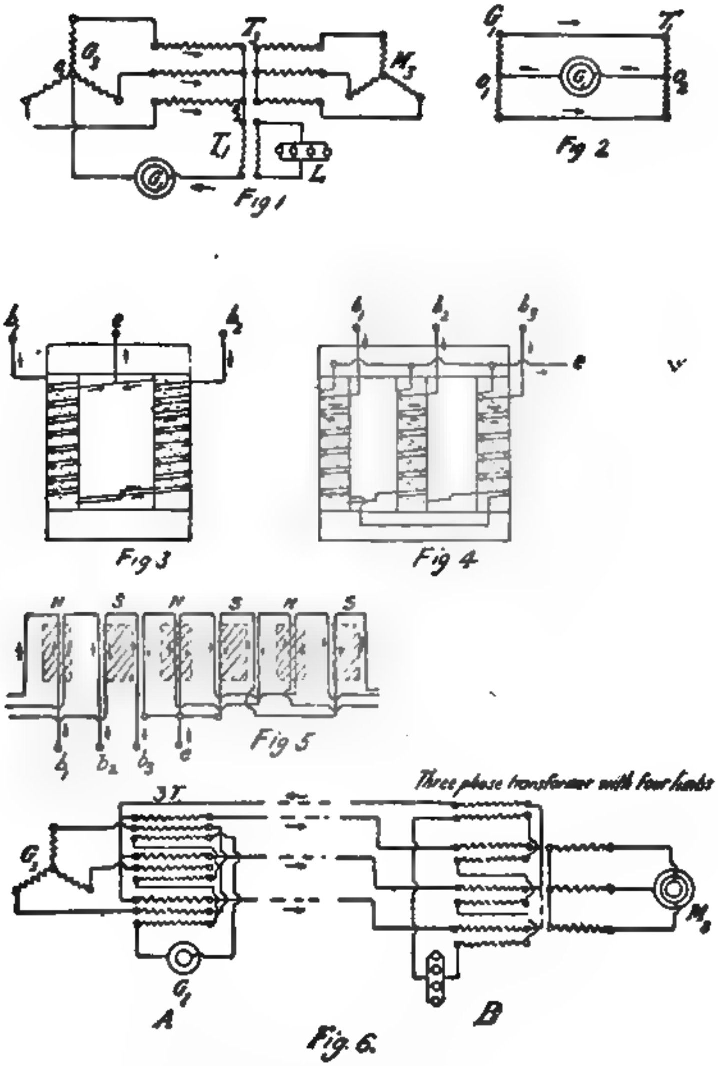
2. The regulation of the lighting pressure is simple.

3. The P.D. for motor circuits is raised, and copper is therefore saved.

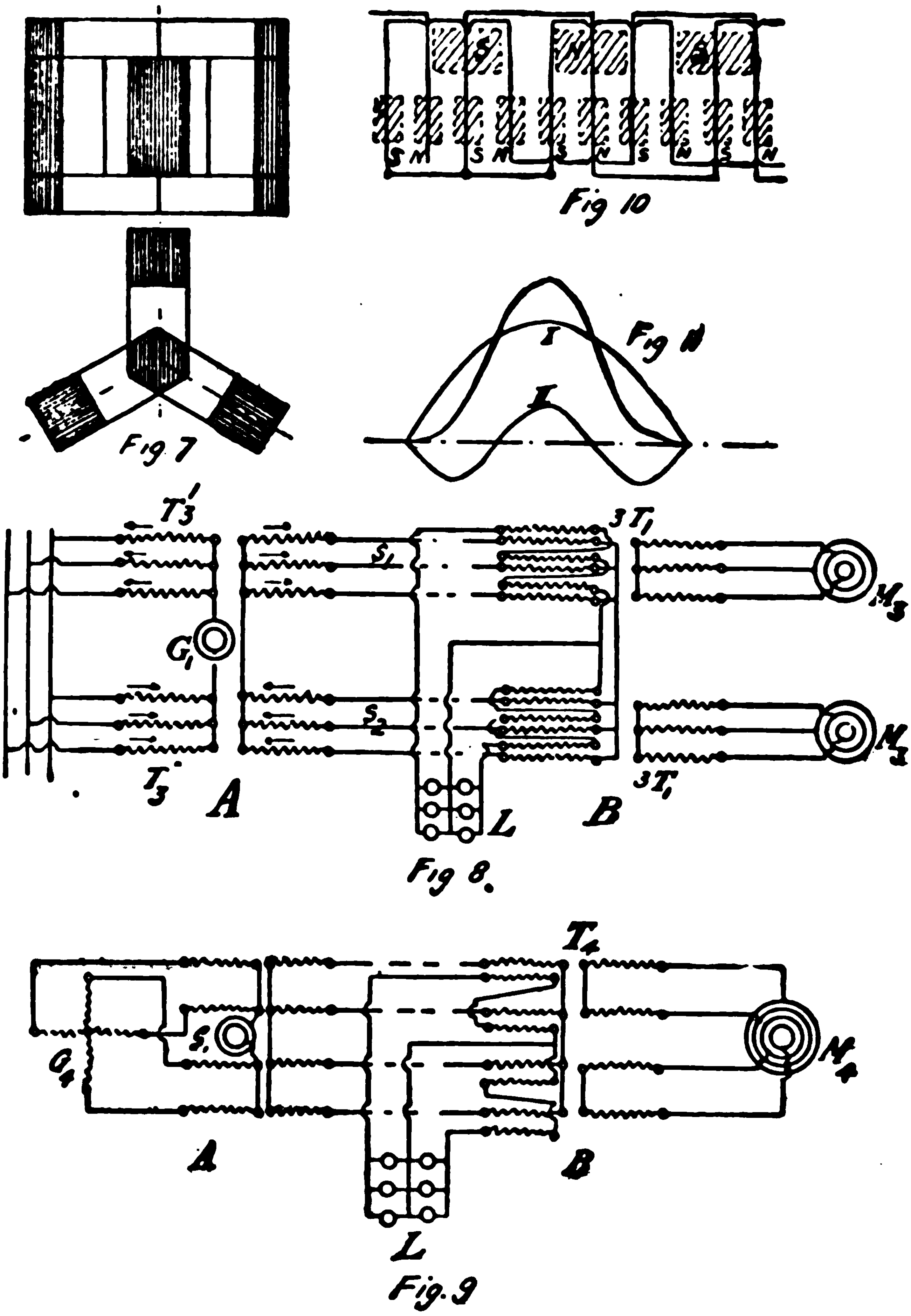
4. The power transmitted with a polycyclic system over mains with a given cross-section is greater than that from a pure single phase plant.

The advantages which the inventors Arnold-Bragstad-La Cour claim for their system, have been confirmed by a series of tests by Dr. F. Marguerre. *

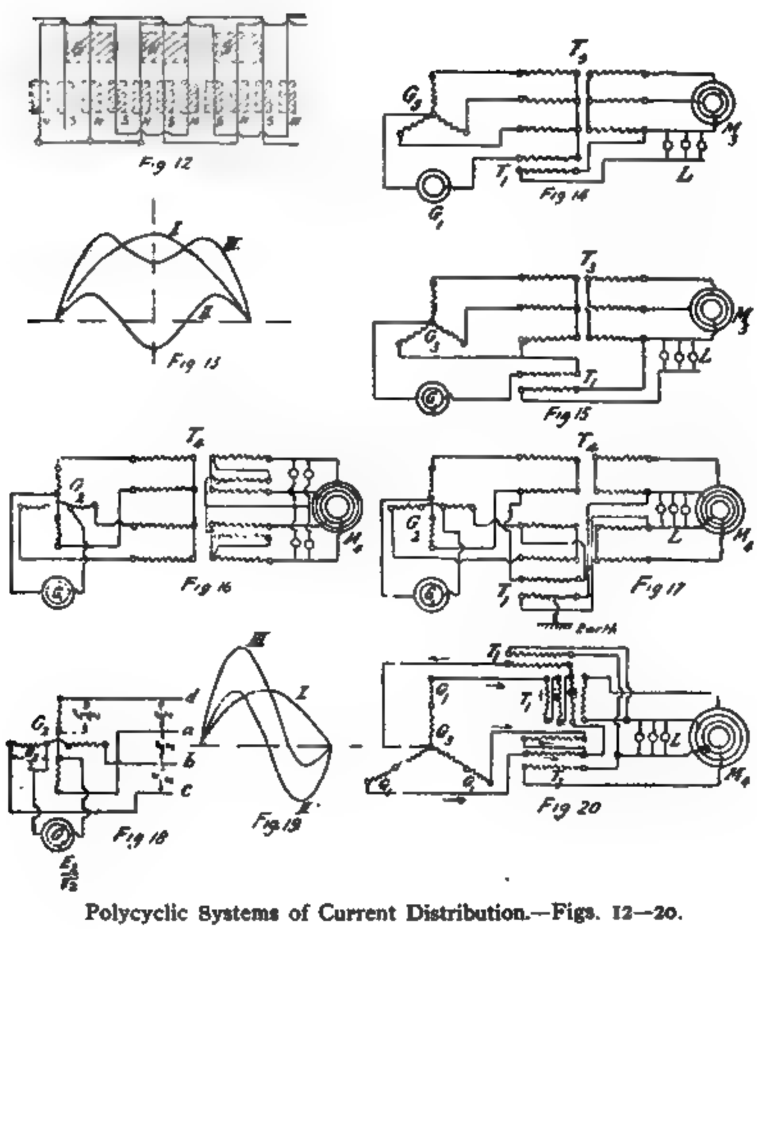
* See "*Experimentelle Untersuchungen am Polycyklischen Stromverteilungs system Arnold-Bragstad-La Cour.*" F. Enke, Stuttgart.



Polycyclic Systems of Current Distribution.—Figs. 1—6.



Polycyclic Systems of Current Distribution.—Figs. 7—11



Polycyclic Systems of Current Distribution.—Figs. 12—20.

41—FURTHER EXPERIENCE IN THE BACTERIAL TREATMENT OF SEWAGE.

By J. C. S. Beynon, A.M.I.C.E.

Since writing my paper on the Septic Tank System for the Treatment of Sewage before your Society in 1904, a great advancement has been made in its adoption all over the world, and many towns in England which were in the depth of despair as to the disposal of their sewage have been enabled to get over the difficulty and to produce a final effluent so pure that it can be discharged direct into the river, and, in many cases, samples of the river water taken below the discharge of the sewage effluent have on analysis been found to be much purer than samples taken immediately above, thereby proving that instead of having a detrimental effect as heretofore, it is highly beneficial.

In this country, although slow in being generally adopted, it is gradually being accepted as the means for the disposal of sewage, but then, of course, conditions are altogether different, as here the pail system is in vogue, and to alter to the more sanitary water-borne drainage entails a large expenditure in the initial cost, but effecting a great saving in the annual charges, which is an ever-increasing one. On an improvement of the financial conditions of the country, there is no doubt that a much greater advancement will be made in the proper sewering of the towns, as with the increase of population the pail system, with its accompanying disposal of slop water, the annual working costs will make it prohibitive.

For towns in this country, where land is obtainable, and which is generally the case, the better plan is to merely liquefy the solids in Septic Tanks and then irrigate the land, as water, being so valuable a commodity, it certainly should be made use of and not allowed to run away into the nearest spruit. On the other hand, if land is not procurable or suitable for irrigation, then artificial filtration is necessary for further purification. This can be done on a small area of ground by filter beds, the final object in either case being the same, namely, the oxidation of the organic constituents, and their conversion into stable products incapable of further putrefaction.

In treating the sewage bacterially, the general method is to run it into tanks, the capacity of which is generally made to hold 24 hours' supply. Latterly the view is held that this can be considerably reduced, but I think it entirely depends on the strength of the sewage; if it is in a crude state and not broken down by passing through any great length of sewers, then the full time is required; on the other hand, if it is kept too long overputrefaction takes place, which means offensive odours. There is no need to cover these tanks unless in close proximity to dwellings, as after a short time of working a scum forms on top, which prevents any smell arising. The gases generated are carbon dioxide, hydrogen, nitrogen, and marsh gas, the latter being as much as 75 per cent.; this gas is inodourous, and burns freely. Submerged walls and dipping slabs are constructed in the tanks, so that the course of the fluid is alternately ascending and descending.

With domestic sewage these tanks will often go for many years without any sludge requiring removal, but with town sewage, in which foreign elements enter, sludge has to be dealt with, and it is then better to build the tanks deeper, and with a conical bottom, so that all the deposit drops towards the centre. This is then discharged through a pipe at the bottom, or pumped up through a chain pump; by this means the working of the tank is not impeded or delayed. The sludge itself can be run off into shallow trenches, the water soaking into the ground. The sun dries the remainder into a friable cake, which makes excellent top-dressing, and there is scarcely any smell with it.

After the solid matter has been liquefied in the tanks through the agency of bacteria, the final treatment of the sewage is the oxidation of the ammonia and organic compounds, the oxidation of the ammonia into nitric and organic acids, which combine with lime, soda, and other bases in the sewage to form nitrites and nitrates of the latter. This is called nitrification, and the changes are effected by ærobic bacteria. This change can be effected by applying the effluent to land (known generally as broad irrigation or intermittent, downward filtration), contact beds or percolating filters.

In contact beds the effluent from the Septic Tank is collected in tanks in which the filtering material is contained. The bed is allowed to fill, and then a period of rest is allowed when filled. It is then discharged and the effluent is allowed to flow away, or a second filtration given if further purification is required. A set of four tanks is constructed, so that when one tank is filling, another resting full, and a further one is being discharged and aerating, and a spare one is also provided, so that each filter in turn can be cut out for two or three days' complete rest, so a complete cycle is formed. The action of the filter is twofold: (1) it collects all gross particles of suspended matter on the filtering material, (2) it effects the oxidation of organic matters by bacteria. It is essential that the discharge be quick and the bed effectually drained and allowed time for aeration. The depths of these filters are constructed from two to six feet, and equally good results have been obtained from either, so that the depth of the material does not seem to make much material difference.

Various materials have been tried for filtering—broken glass, cinder, coke, coal, gravel, and broken stone, but clinker is generally used when obtainable, that from a destructor being preferable. The most important part about the material selected is that it should not break up or disintegrate, as it then settles down and becomes clogged. In contact beds, clinker broken down to a ¾in. mesh is as good as anything, but it must be washed and freed from all dust.

The diverting of the effluent from one filter bed to another can be done by hand, but as this entails careful watching, and has to be done at night time as well as day, it is usually effected by automatic gear, of which there are several kinds. These in their turn require a good deal of attention, but they regulate the period of rest when full and empty far better than can be done by hand.

Percolating filters, or trickling beds, are those in which the effluent is showered or sprayed on to the surface of the filtering medium, either continuously or intermittently, and allowed to slowly percolate through; these beds are constructed on a concrete floor, and the filtrate flows off this and is collected in a channel, and then flows away.

The distribution is done by revolving or rotary sprinklers, fixed sprinklers, or Stoddart's trays. The latter is continuous, while the former are either intermittent or continuous. My experience is that it does not effect the result very much, as long as the filter can at times be given a rest, say for two or three days. It is essential that as much air as possible be conducted to the interior of the bed, and for this purpose air drains are laid on the floors, which permit of the air to penetrate into the body of the material, which is aided by the downward flow of water; the exterior walls of this filter need not be built up solid, as in the case of contact beds, but can be built up to suit the natural slope of the filtering material used. This is, of course, a great saving in cost.

The depth of these filters should be at least six feet. This fall is not always obtainable, and they are sometimes constructed only three feet deep; but the results cannot be expected to be so good, and contact beds would be better for anything under four feet.

These beds are worked up to 1,000,000 gallons per acre per diem, but the sewage would require to be weak, and 500,000 gallons is the usual maximum for any town sewage.

The filtering material in these beds is considerably coarser than that used in contact beds, being up to 2in. and 3in. cubes. The usual material is clinker, but stone or coal is often used, and it is considered by many that the smoother surface gives the better results, for in clinker the effluent collects in the crevices, which becomes stagnant; capillary attraction also helps to keep the material water-logged, which is highly undesirable, but the most important point, as in contact beds, is to obtain material that will not disintegrate.

The advantages of Contact Beds over Continuous Filters are:—

(1) The distribution need not be so carefully considered.

(2) Much less fall is lost, which is often a most important factor.

The disadvantages are:—

(1) That watertight tanks must be constructed.

(2) Oxidation is limited, as the amount of air is only equal to the volume of sewage.

(3) The beds are far more liable to clogging.

(4) The capacity of beds must be much larger for the volume of effluent treated.

The advantages of percolating filters are:—

(1) Percolating filters cost less, as no retaining walls of any kind are necessary.

(2) The air supplied to intermittent filters may be more than five times the volume of the sewage treated, therefore more highly oxidised effluents are attainable.

(3) The filter does not deteriorate if properly made, the only plugging which takes place being on the surface.

It will be seen that, on the whole, the advantages rest with percolating filters; there are, however, circumstances in which contact beds may be preferred; this may be the case where the subsoil is so stiff a clay that the beds may be watertight without any retaining walls, and where there is little fall.

The advantages of the bacterial treatment of sewage is that the smallest populations can be as effectually treated as the largest towns, the area of ground required being small in comparison with land treatment.

In private houses the sewage varies greatly in strength and quantity; sudden flushes of water from baths causes too quick a flow through the tank. This has to be provided against by ponding the sewage in the tank, allowing only a small flow to pass through an aperture, provision being made to pass any further increase or excessive volume by an overflow pipe.

Grease must be rigidly kept out of the tank. This is done by providing efficient grease traps to catch the slop water from the kitchen and pantry. The soapy water from laundries must also be treated in the same manner, and the hot water should be cooled off by having the traps of sufficient size to permit of this. These traps require to be cleaned of the grease frequently.

The great difficulty in all these small installations is to overcome the smell which emanates from the effluent of the Septic Tank when being distributed on the filter beds. In many cases it has been necessary to construct these installations close to the dwellings, sometimes within 40 feet, and, of course, if any smell, it is highly disagreeable to the occupiers. As it is impossible to get rid of the smell entirely, I find it best to enclose the filter bed in entirely on the top, and to have a fresh air inlet and an outlet, which can be carried up, say, 12ft., or fixed against some adjoining wall or building, when any smell will be carried up this vent pipe and distributed without any annoyance. This is only necessary when the installation has to be put down in a confined space.

Percolating filters are, I think, more suitable for small installations, as an effluent is obtained by one bed quite equal to that obtained from double contact, and the cost is less in construction.

The best distribution is obtained by Stoddart's trays. The liquid is brought into a gutter, overflows the margins, and, on reaching the under surface, meets with a series of drip points, from which it drops upon the filter. There are no mechanical parts about it, so it is impossible to get out of order from this cause, and the only attention required is the occasional brushing out of the troughs. Another good point is that it is completely unaffected by variations of flow, whether great or small.

The effluent from the filter bed can be used for watering the garden. A cubic yard of filter is required for 15 persons; where the drainage from stables is taken in, it is usual to allow one horse equal to five persons.

The bacterial system is very adaptable for native compounds, a great saving being effected in the annual cost, compared with the pail system.

The initial cost of an installation and drainage varies from 17/6 to 20/- per native; this includes drainage, building of latrine, and purification works.

In the latrine troughs containing water are provided; two troughs are allowed for a thousand boys, but six will be sufficient for four thousand. These latrines are each about 22ft. 6in. long, and contain 6in. of standing water. At regular intervals these are flushed out by a discharge of water by automatic cisterns of 100 gallons each, all the contents being washed into the drains. Urinals are also provided. The floors of the building are laid with granolithic pavement, which can be easily washed down, so that perfect cleanliness is obtained.

The drains conduct the sewage to the Septic Tank; after passing through the tanks the effluent is distributed on to the filter beds. The distribution is effected by revolving sprinklers, of which there are various types on the market. Fixed sprinklers are also used, which spray over the bed; these are good when the flow is constant, and sufficient head of water is obtainable.

If the filtrate is required to be very clear, and the water returned to be used over again in the latrines, it is advisable to have straining beds. These are filled with sand, in which the liquid is filtered through at a constant head. Any flocculent matter is thus caught, and on the flow becoming too slow the bed must be drained off, and the film formed on the top of the sand raked off and thrown on one side. The filter will then be ready for work again.

The working cost of this system is very small, as after the first charge of water, which must be at least 15 gallons per head of population, only a small amount is required per diem for freshening purposes. This is often obtained from the washing out of the kitchens and that used in the cooking, so that the only direct charge is the pumping back of the water.

The purification effected by the filter in an intallation of this kind is shown by the following table:—

Oxygen absorbed 4 hours.		Alb. ammonia.		Nitric nitrogen.
In grains per gallon.				
Tank Eff.	Filtrate.	T.E.	Filtrate.	Filtrate.
5·64	·95	·598	·397	·537

For the information of those who are unfamiliar with analytical methods, it may be mentioned that the reduction of organic ammonia in the filter, compared with the tank effluent, affords a very good

index of the decrease of the putrescent matter, and therefore of the efficiency of the filtration. Also the amount of nitric nitrogen in the filtered effluent indicates the extent of conversion of putrefactive nitrogenous matter in the tank effluent into non-putrefactive nitrogenous compounds, so that the higher this figure is the more active, as a general rule, is the purifying power of the filter.

The question of sewage disposal is a highly technical one, and only those who have had practical experience can imagine the difficulties which have to be overcome, and therefore Local Authorities and others who have this matter to deal with should be careful before committing themselves, unless advised by experienced engineers, as a method of disposal which may answer in one case may prove useless in another. It is important to remember that it is a chemical and bacteriological, as well as an engineering question, and the chemical composition of the sewage, which I have previously mentioned, varies greatly, and has to be taken into consideration in forming an opinion as to the method which is likely to prove most satisfactory.

In conclusion, I wish to say that the evidence given before the Royal Commission of Sewage Disposal has been of the greatest value to the Sanitary Engineer, but until the Commissioners' final report is published we are not in a position to say which of the bacteriological methods at present recommended is the best; and no doubt, as I mentioned above, this to a large extent is governed by the circumstances in each case; neither can it be said that we have arrived at finality in our knowledge as to the best means of availing ourselves of Nature's processes, but that we are on the right lines is perfectly certain.

42—THEORETICAL INVESTIGATIONS REGARDING FERRO-CONCRETE

BY H. KESTNER, C.E.

There can be no question that the use of reinforced concrete as a building material has made steady progress in England, America, and on the Continent during the last few years, so that one is justified in asking, Why has this building system been so much neglected in South Africa?

To arouse some interest and to draw the attention of engineers to this system of construction will be the object of this paper.

The practical use of ferro-concrete is of course known to every engineer, and it is only the theory which has not kept pace with the progress of this form of construction, about which there still exist very vague and erroneous views, especially with regard to the statical action of this method of construction. The reason that the theory has not kept pace is on account of the rapid development of ferro-concrete building.

A method of calculation conformable for the purpose must, as far as possible, correspond with the existing statical action of both materials forming the ferro-concrete, *i.e.*, concrete and iron. Only under these conditions can safety and economy be gained. Very much depends on the kind of calculation adopted, and as to whether the formulæ are very long and intricate, or simple and easy of comprehension. It must at once be confessed that the various theories about ferro-concrete in the vain hope of obtaining complete accuracy, make the calculations so intricate that they are completely useless for the purpose they are intended. Every engineer who is a friend of this new building system, and is desirous of assisting its progress, should avoid these faults and only choose the simplest formulæ.

The most accurate theories which always consider the elastic qualities of both constituent materials, concrete and iron, in every point, have their fundamental rules always connected with certain presuppositions, and this disqualifies them of the term accurate, but on account of the care which has been applied in the solution of the question they are the most meritorious theories at present we possess.

In the present state of the theoretical investigations, it is in my opinion more justifiable to adhere to a theory connected with presuppositions instead of adopting a fallacious accuracy. It naturally depends entirely on the more or less careful investigation of the basis of this theory. This will be the object of my paper, and I will make use of the facts which experience has taught us.

CO-OPERATION OF CONCRETE AND IRON.

In the theoretical investigation of ferro-concrete it is generally accepted that the concrete is in a position to follow the iron in its changes of form through tension, compression or other strains. If we place instead of the modulus of elasticity of the iron the letter Ee, and of that of the concrete the letter Ec, we assume that the [illegible] strains of the reinforcement, and of the concrete,

which adjoins the reinforcement, are in the proportion of Ee to Ec. Most of the theorists have accepted this fundamental rule as a basis of their formulæ, without investigating the correctness. It is, however, of great value to examine it more closely in order to prove whether this fundamental rule can be accepted or whether it is possible to disregard it completely.

Experience has not given us many facts to answer these questions. Harel de la Nae, a French Engineer, assumes that in a ferro-concrete body under strain the cross-section shows a point of contraction, but only then when the limit of elasticity of the concrete has been reached. According to this engineer's assertions, the slipping of the reinforcement within the body can either be caused by the elongation of the iron when it reaches the limit of elasticity, or by shearing of the concrete. These assumptions are completely proved by loading tests which were carried out to the breaking of test pieces. Should the breaking of such a test piece occur in the centre, the adhesion of the concrete to the iron ceases through the elongation of the iron. Should, however, the test piece break near the supports, the reinforcement is dislocated by the shearing forces. This proves that the adhesion of the concrete to the iron is attacked by external forces which at a certain limit destroy the adhesion. In any case it is most interesting to know whether these forces give such an elastic change to the form of the body before reaching the limit, that both materials cannot be considered as co-operating.

From the purely theoretical point of view it is evidently inaccurate to assume that the fibres of the concrete and iron lying close together are in the same way pulled or compressed.

Even when shearing stresses resulting from the external forces are not appearing, the diversity of the material must necessitate a particular connection between concrete and iron at the point where both materials come into contact with one another. It cannot be disregarded that the theory of elasticity can really only be applied to bodies of the same material. The theory of the strength of materials which does not permit of the consideration of all irregularities in the shape of the homogeneous bodies, is more difficult to apply to the elastic change of form of those bodies which are built up of irregular voids, cracks and widely differing materials. Differently composed bodies do not therefore allow a purely scientific investigation. If we now consider the shearing strains which under the influence of the load come into action at the point of contact of the iron with the enveloping concrete, then we find a fresh reason for the probable disconnection of the concrete and the iron. At another page of my paper I will refer to the fact that the cross-section of a homogeneous body under a bending moment must be subjected to changes of form through shearing forces. In the ferro-concrete body the shearing force, which the iron exercises on the concrete, must have a reaction of the same kind. Experience does not give us any facts regarding the value of the modulus of shearing elasticity, and on the other hand such elastic changes of form are not taken into consideration in the calculation of the homogeneous

bodies. It is, therefore, conformable for the purpose and in accordance with the usual stability calculations, to disregard the elastic change of form resulting from the shearing forces. One must therefore be satisfied to admit an eventual elastic sliding of the iron in the concrete without being able to take the change of form into consideration. All practical tests have proved that the iron takes an actual part in the elongations of the concrete.

UNIFORMITY OF FERRO-CONCRETE.

Uniformity in the ferro-concrete is the chief factor, and upon this the complete co-operation of the iron and the concrete entirely depends. There is, for instance, the Monier system; in this system a reinforcement of iron rods of small cross-sections are used, which are divided in the concrete in regular and short distances, and thereby both materials are as closely as possible connected with one another. For such a system it must be admitted that the smallest particles of the enveloping concrete take an active part in the bearing of the stresses, to which the reinforcement may be subjected. If, however, the reinforcement is limited to only a few iron bars of larger diameter, or if it consists of profilated iron embedded in greater distances from one another, the co-operation of both materials will not be the same as in the former system, and the actual bearing power will be less if these reinforcements are not interlocked by cross-connections.

This has been fully recognised by practical men, and most of our constructional systems are based upon the principle that it is better to divide the reinforcement uniformly, and to distribute iron rods of smaller cross-sections at shorter distances. A construction disregarding this principle cannot be acknowledged as a ferro-concrete building system, as the assumption of the co-operation of both materials is not applicable with such a form of construction, and economy cannot be effected as they require a greater factor of safety. This will be especially proved with ferro-concrete constructions under a bending load, which naturally causes shearing stresses. The disadvantage of a reinforcement of greater cross-sections will not be so apparent with parts under compression or with bridge arches where shearing stresses of importance seldom appear.

IMMUTABILITY OF THE CROSS-SECTIONS.

The common law of the strength of the building materials is based upon the following assumption:—

Each cross-section of a prismatic body, which is subjected to stresses caused by external forces remains even during its change of form, and all scientists engaged in the investigation of ferro-concrete have accepted this law as a basis for their researches. It may, however, be possible that this assumption is not correct. I may mention that it has been proved through extensive tests, that in concrete bodies under tension, the tensile strains are not equally distributed over the cross-sections of the body. This fact proved

by the above-mentioned tests will doubtless exist in ferro-concrete structures under a bending or compression load. Supposing we had to investigate a column or a concrete wall, I am sure you will agree with me that the assumption of the immutability of the cross-sections cannot be correct, at least not at the point where the external force strains the structure, as the load is always distributed over a more or less extensive area of the surface of the structure. But the impossibility to estimate the manner of load distribution in structures makes every investigation in that direction dubious.

If we take the case of a body under a bending load, we will also find that the assumption in question does not possess a scientific basis. The law of bending, as taught to-day, shows us that the assumption of the immutability of the cross-sections was originated for the purpose of simplifying our calculations. In certain limits, however, it was possible to prove this assumption through tests which were made with bodies of rectangular cross-sections, but nothing has confirmed it with bodies of irregular shape, but on the other hand it is known that the immutability is incompatible with the existence of shearing stresses, because these cause the section to curve into an S-shaped form.

LAW OF THE ELASTIC POWER.

Through the two above-mentioned assumptions, the manner in which a body of ferro-concrete changes its form is defined, and it only remains to determine the law, which will define in the equilibrium actions the elastic power of the concrete in connection with the corresponding changes of form.

This question has troubled theorists very much, and has been the cause of long disputes.

To make the point in question as clear as possible, we will only consider the condition of prismatic bodies subjected to bending.

I

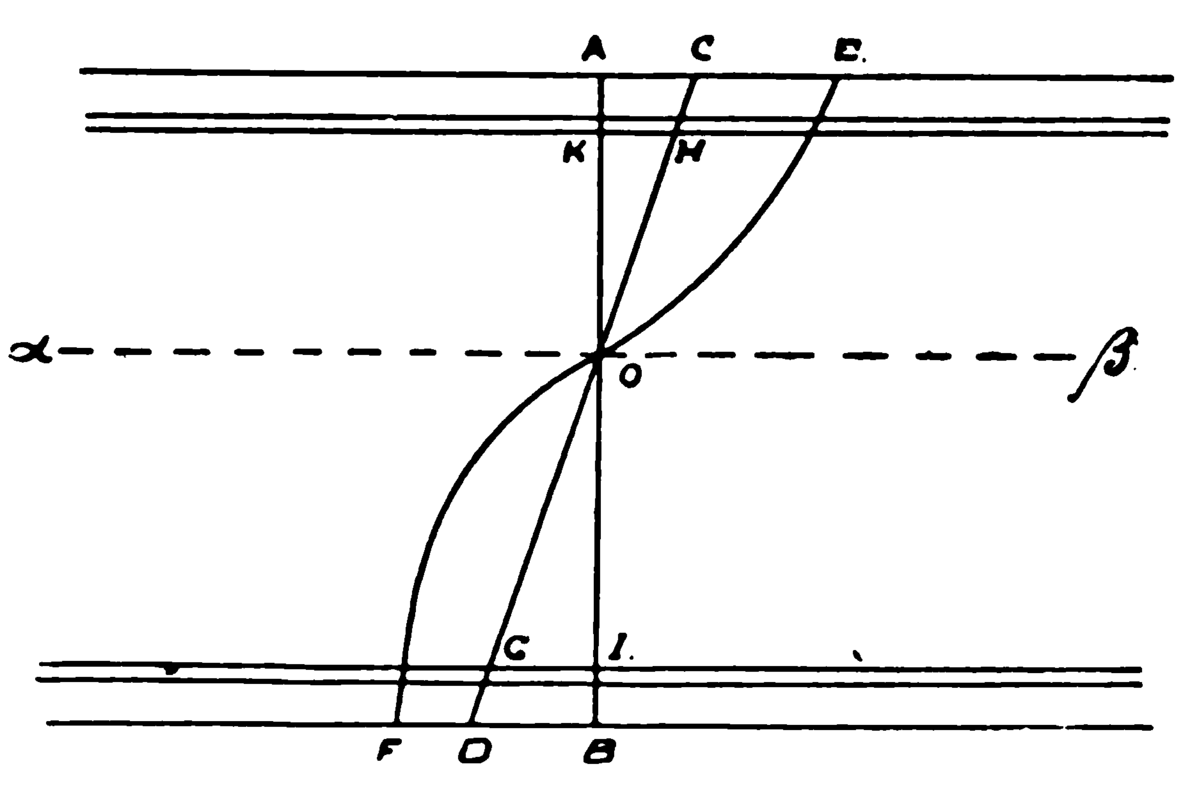


FIGURE I.

Assuming that the assumptions are correct, the line AB shows the cross-section after the change of form, and the line CD represents the same cross-section before the change of form. The compressive or tensive strains in the concrete above and below the neutral axis respectively, are values depending upon the changes of form of the body equally increasing from O to AC and from O to BD. These are represented by two curves OE and OF which in a body of rectangular cross-section are nothing else than the law of the change of form of the concrete through compression or tension, and the latter was constructed by accepting on the one hand O α and OA, on the other hand O β and OB as co-ordinate lines for the strains and changes of form respectively. As the reinforcement takes part in the changes of form of the concrete, it is accepted that the cross-sections K and I of the iron bar are removed to H and G in the line CD, which enables the strain to be determined as a value depending on the modulus of elasticity. As all relations connecting the strains with the changes of form are known, one can succeed through two conditions to determine the elastic powers in the horizontal direction, which are transmitted between the two intercepts divided by the line AB, one being the moment, the other the projection. The problem is therfore solved as soon as it is possible to determine the equation of the curves OE and OF.

In the following I will refer to the different strains appearing in different structures, in order to prove the probability of the assumptions above mentioned. The most simple of all strains is resulting from compression, and this has to be specially dealt with in the statical calculation of columns.

COMPRESSION.

The compressive strength of concrete depends entirely upon the proportion of the mixture, the shape and the height of the test bodies. With small concrete bodies the strength is very great, it diminishes with the increasing proportion of the height to the width; the strength of the cubic bodies is known as the cubiform strength of the concrete. In the high test bodies, the rupture occurs through removing the sliding resistance in inclined planes, and the compressive strength, which generally cannot be taken into account, then appears very small, when dividing the crushing load by the sectional contents. The purpose of the reinforcement in the columns is thus to prevent that sliding to inclined planes. Round iron vertical bars interlocked with horizontal iron hoops, are usually employed for the reinforcement of columns. This arrangement affords the advantage that by the eccentrical loading of the columns, it can still sustain tensile strains. For the compressive strain on the axis, the calculation is made under the supposition that the concrete and the iron are equally compressed. Thus if fc means the sectional contents of the concrete, fe that of the iron, dc and de the corresponding strains of both materials, the load P will be :—

$$P = fc \times dc + fe \times de$$

dc and de are thus tensions in the concrete and the iron, which correspond with the same compressions. We must therefore apply the law of the elastic strain for concrete.

The latest investigations by Considere led to the discovery of quite a new system for the reinforcement of columns, which system is especially recommended for heavily loaded columns, of which, for certain reasons, the diameter must be chosen as small as possible. His publication on "Le beton frette," which is best translated by encircled concrete, appeared some time ago in the French Journal, *Genie Civil.* They are the results of experiments with concrete cylinders, the reinforcement of which consists of spirally wound iron bars. This system allows a more effective use of the material than the ordinary vertical reinforcement; it is 2.4 times stronger than the latter. The strength of the concrete can thus be increased up to 11,500 lbs. per square inch, and is consequently practically quadrupled. The calculation for reinforced concrete columns should be done in the following manner :—

The cross-section of the iron is multiplied by

$$a = \frac{Ee}{Ec} = \frac{\text{elasticity of iron}}{\text{elasticity of concrete}} = \frac{3000000}{300000} = 10,$$

and the result added to the sectional area of the concrete. Then the strain of the concrete is equal to the loading force, divided by the cross-section of the column, and the strain in the iron consequently is ten times the strain in the concrete. On the basis of Euler's breaking formula

$$P = \frac{\pi}{l^2} \times e \times j,$$

and the formula which in bridge construction is known as Rankine's breaking formula, namely :—

$$d_k = \frac{K}{1 + 0{\cdot}0001\ (1 : i)^2}$$

and further on the basis of the formula for the strain of the concrete (and of the cast iron)

$$d_k = K\ (1 - e - 1000^c)$$

the calculation of reinforced concrete bodies under compression can easily be made.

DEFLECTION.

In demonstrating the deflection in ferro-concrete constructions, I will first refer to the ordinary bending :—

The fluxure equations with the homogeneous bodies with constant coefficients of strain are obtained as mentioned before, on the assumption that the vertical sections, straight before the bending, also remain straight after the bending, although that assumption is incompatible with the presence of the shearing strains, as the latter cause

an S-shaped curve of the sections. With equal force such an assumption can be applied to the deflection of reinforced concrete bodies. The question whether the tensile strength of the concrete shall be taken into account with the deflection caused some diversity of opinion. By practical engineers the point at issue was settled from the beginning, with the result that the tensile strength of the concrete is not considered at all, and the full permissible tensile strength of the reinforcement at the side of the tension is used. On that sound basis the theory since then has still further been developed, and greatly assisted by the elasticity experiments. This theory, in which the tensile strength of the concrete remains unconsidered, is supported by such authorities as Emperger, Christophe, and Considere.

It is mainly owing to the endeavour to theoretically explain the favourable adaptability of ferro-concrete that many methods of calculation were brought into existence, mostly by theorists. The oldest methods take the tensile and compressive elasticity of the concrete as equally great, subsequently the modulus of elasticity for concrete was taken smaller, then parabolic curves were taken for the elongation curves, and at last, through Considere's experiments, the line of tension of the concrete under strain was represented by a straight line being parallel to the cross-section. It must be observed that with such assumptions formulæ must be obtained, the length of which may be regarded by the authors to reflect the most minute accuracy and reliability; for the constructing engineer, however, these intricate formulæ offer little inducement for their employment. Further, the substitution of the elongation curve is less correct, than the substitution by a straight line, because for the law of power the exponent m is nearer to 1 than to 2, and the elongation curves would have to be forced into the shape of a parabolic curve. But apart from all that, these methods of calculation do not afford the desired degree of safety; and they can become somewhat dangerous if the percentage of reinforcement in the concrete chosen is too small. Considering that the concrete is liable to crack, caused either through faulty preparation or interruption during the concreting or by drying too quickly, one cannot reckon on a uniform tensile strength of the concrete. Under the circumstances, there is, therefore, no protection against cracks in the concrete under strain, and, for instance, in loading tests small cracks occur frequently at an early stage, originating from the tension, in the body, the cause whereof is as yet unknown. At any rate, the exact time when these cracks appear on the side of tension cannot be predicted with certainty. Further, considering that the object of every statical calculation is less the precise demonstration of the strains in a structure under load than it is proof of a sufficiently great factor of safety in the structure, the tensile strains of concrete must not be considered, for the reason that its tensile strength cannot surpass the limit of elasticity of the iron, thus already giving way before the point of rupture is reached.

For a rectangular cross-section we can deduct formulæ for the calculations of the dimensions, if the elongation curve of the concrete is known. In Fig. 2 the line represents the line of the strain, which is identical with the elongation curve of the concrete; for the compressions are proportionate to the ordinates, while the abscisses represent the corresponding compressive strains. On the side of tension the tensile forces of the reinforcement only act, and will be reduced to the unit of the width. The line from the central axis O to the centre of the reinforcement is defined through strain, which corresponds with the permissible strain of the iron. The area of strain of the iron is a rectangle, the basis of which is of smaller dimensions than the height. Assuming the permissible strain for the concrete to be 750 lbs. per square inch, the maximum area of the concrete is thereby limited above the neutral axis. Under

II

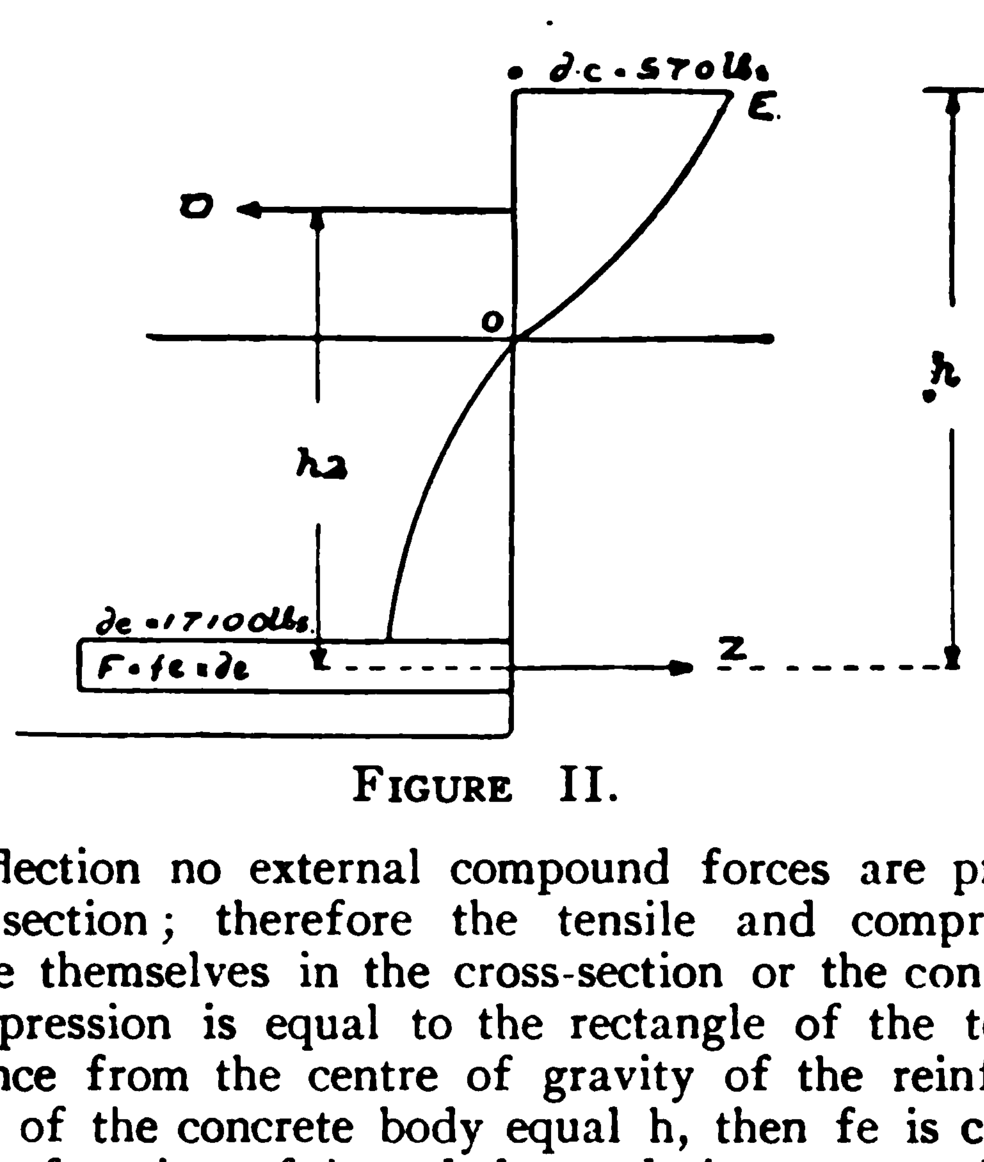


FIGURE II.

ordinary deflection no external compound forces are present in the longitudinal section; therefore the tensile and compressive forces must equalise themselves in the cross-section or the contents of the area of compression is equal to the rectangle of the tensile force. If the distance from the centre of gravity of the reinforcement to the top edge of the concrete body equal h, then fe is calculated by means of the function of h and dc, and the moment M, which is equal to the contents of the area of compression multiplied by the distance of the same from the centre of gravity of the reinforcement, will be found as the function of hz or h, and fe is found to be proportionate to the square root of M. By this method the dimensions of a construction can easily be determined, while through circumstantial test calculations it is only possible to find the strain of an existing construction.

The same method can be applied purely analytically by the use of the law of power, whereby the thickness of the concrete and the reinforcement for given strains is obtained proportionally to the

square root of the moment M. For the law of power can then also be substituted the proportion between the elongations and the strains, so that we obtain the distribution of the strain as shown in Fig.

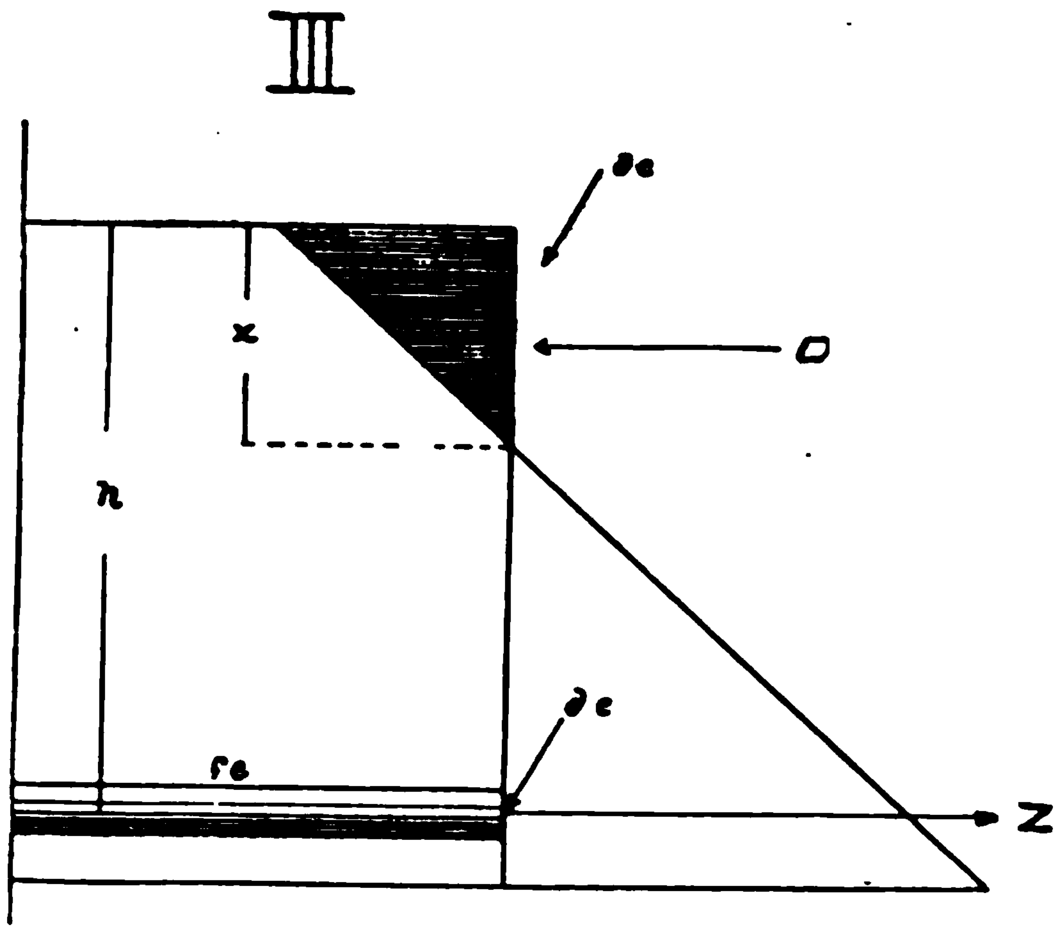


FIGURE III.

No. 3. Through the equality of the tensile and compressive force, and on condition that the elongations of the concrete and iron are proportionate to the distance from the neutral axis, we obtain for the calculation of the distance x of the neutral axis, the quadratic equation :—

$$x^2 + 2fe \times a \times x = 2fe \times a \times h,$$

wherein

$$a = \frac{Ee}{Ec} = 10.$$

Having obtained x, it is possible if Z represents tension, and D compression, to find that

$$Z = D = \frac{M}{h - \frac{x}{3}}$$

and

$$de = \frac{D}{fe} \qquad dc = \frac{2 \times D}{x} \quad \text{respectively.}$$

This method thus enables the experimenter to determine in a simple manner the strain of a given construction, but formulæ can also be given for calculating the dimensions of a construction to be erected, namely :—

$$h = \frac{de + a \times dc}{dc} \times \sqrt{\frac{6M}{a(3 \times de + 2 \times a \times dc)}}$$

$$fe = \frac{h \times dc^3 \times a}{2 \times dc\ (de + a \times dc)}.$$

For given values of dc and de, h and fe are obtained proportionate to the square root of M.

It frequently occurs that in the cross-section also the compressive zone is reinforced, for the purpose of obtaining a higher compressive strength, or to have a sufficiently strong reinforcement for changing moments.

THRUST.

Apart from ordinary deflection, the deflection by thrust can come into operation, as it usually occurs with bridge arches. If there are only compressive strains on the whole cross section, then the calculation can be made in the same way as in a cross-section of a homogeneous material, if the cross-section of the reinforcement is multiplied by

$$a = \frac{Ee}{Ec} = \frac{\text{elasticity of iron}}{\text{elasticity of concrete}} = \frac{10}{1} = 10.$$

The case is different if the compressive force shows such an eccentricity that tensile strains appear on the opposite side of the cross-section. We then obtain for the calculation of the distance of the neutral axis by a given cross-section and reinforcement, an equation of the third degree, or the small tensile strength of the concrete should exceptionally be taken into account, whereby the calculation for the homogeneous cross-section could be made.

In reinforced concrete arches, or, as they were formerly called, the Monier-Arches, there occur in most cases no tensile strains, provided that the arch is given a serviceable shape. The employment of the reinforcement only serves to ensure a greater safety and to lend a greater compressive strength to the concrete. Should any tensile strains still occur, the following method may be applied provided one does not want a very intricate calculation. The strains of the pure concrete cross-section are first ascertained, and then the total of all tensile strains of the concrete put to the reinforcement on the side of tension.

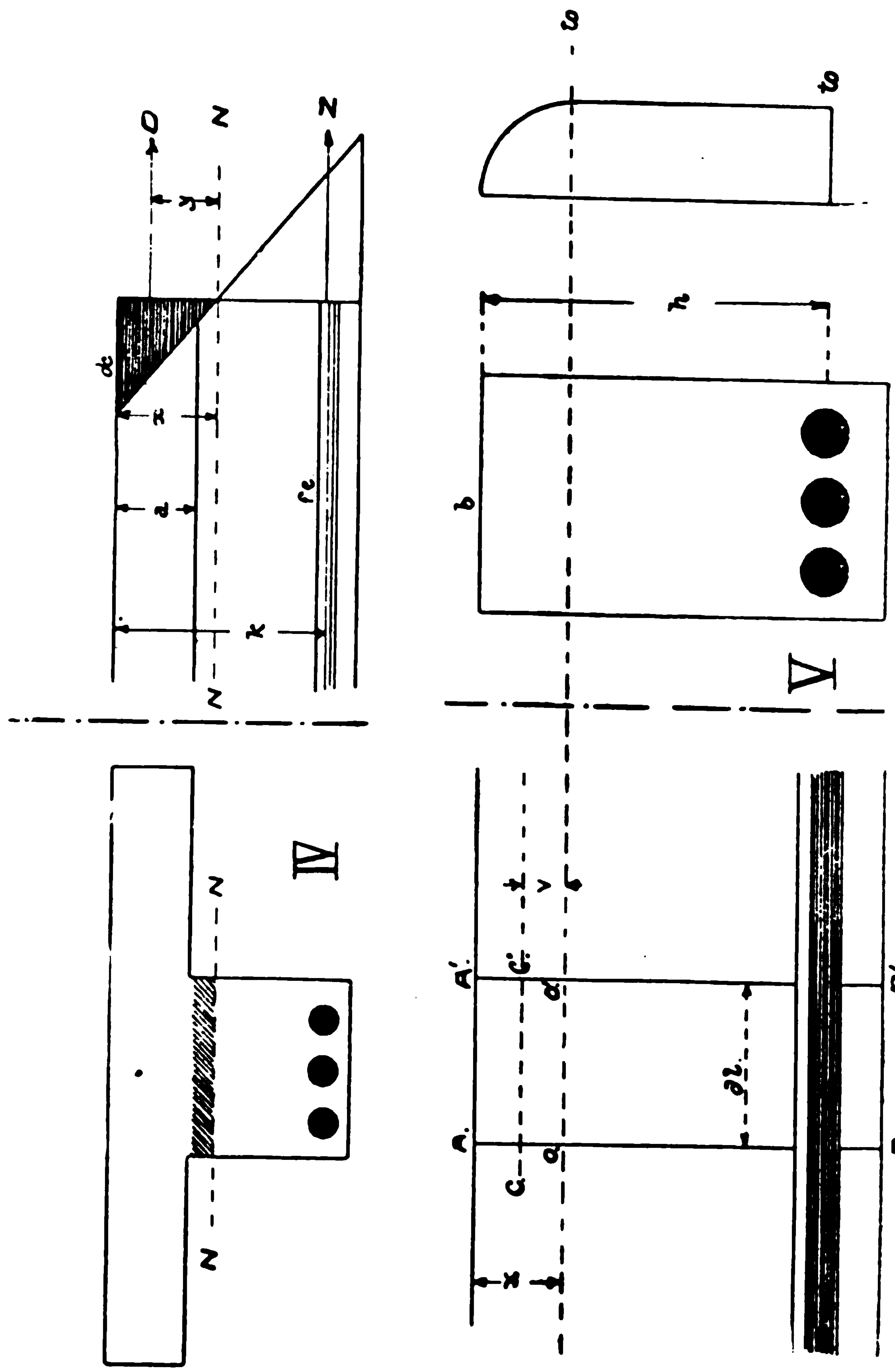
The above-mentioned methods of calculation are meant for the rectangular cross-section only, and are therefore essential for the calculation of the ceilings-plates and arches. It is evident that the plates can either rest free or be fixed on two or more supports, and that accordingly special types for the shape of the reinforcement must be chosen. In these works the reinforcement is placed in the direction of the tension in the lower part of the plate, and in such a manner that the iron is still sufficiently covered by the concrete. The case is a different one with fixed plates, or with plates resting continually over several supports. The moments are in this case negative near the supports, and the moments of the supports proper are rather greater than the positive maximum moments in the centres of the plates. The reinforcement must therefore be placed over and near the supports.

DEFLECTION.

As a rule bent iron reinforcements do not suffice, as the load can change its position, thereby causing a change of the moments. With continual ceilings we have a positive and a negative line of maximum moments, according to which the reinforcement has to be selected. Frequently a reinforcement running right through the upper part of the plate is necessitated, especially if a short and wide span are interchanging. Reinforced ceiling constructions have arrived at such a pitch that it is impossible to refer to them in detail; there are close on 300 different methods of construction in existence, and nearly every week a new system appears, which, however, in most cases does not show any material improvement. Different ceiling systems have the technical fault, that above the supports the reinforcement of the ceilings are placed in the lower part, and not in the upper part of the plate as required by calculation. A progress is noticeable in connection with those ceiling constructions, in which the distance between the tensile and compressive zone is made as great as possible, without, however, considerably increasing the dead weight of the ceilings. This aim can be obtained through groins; so we then obtain groined ceilings consisting of interlocked T girders of concrete, with reinforcement in the lower part of the groins. If these reinforced groins are set apart in greater intervals, which naturally necessitates a stronger construction; the upper part forming the compressive zone, should be reinforced as a plain concrete plate, fixed between the groins, according to the theory just mentioned. Whereby we obtain a groined ceiling construction in which the ceilings with the reinforced concrete form a T profile. From a theoretical point of view a plate strengthened by groins offers a more economical method of using the materials than a plate of a constant thickness. Up to a certain span, however, the greater cost for the centering of the groins will compensate for the saving of material, so that the groined ceilings can only be constructed with advantage with a span of 10-12 feet or over.

In the groined ceilings construction, the ceilings always statically co-operate to a certain extent with the groin. As, however, the bending moments are negative as in the case with fixed girders or with unsupported girders running right through, and thus again the tensile strength of the concrete is not taken into consideration, so the calculation will be found to be the same as if the ceilings were not in existence, that means that you have to proceed the same way shown in the foregoing for the rectangular cross-section, with this difference, however, that the tension zone with the reinforcement is to be looked for in the upper part, while the compressive zone acts in the lower part of the beam. Assuming that the reinforcement of the girder is evenly distributed on the operative width of the plate, then the circulation can also be made with positive bending moments for the rectangular cross-section if the neutral axis lies within the ceiling plate, or lies horizontally with the lower part of the plate.

In reality the neutral axis always lies near the lower part of the plate; the hatched part of the girder, Fig. 4, in which small compressive forces are still active, can simply be omitted without



FIGURES IV and V.

substantially affecting its strength. If we only want to determine the reinforcement, the smallest possible value, namely, the distance between the reinforcement and the centre of the ceiling plate can be

chosen as a lever arm between tension and compression. The strain in the upper part of the concrete of the ceiling plate does not move within such narrow limits as this lever arm of Z and D and this strain should be calculated, for which purpose the following more exact course might be adopted. The neutral axis lies within the distance x from the upper part of the plate in the groin, k to be the distance of the reinforcement from the same part, fe means the cross-section of the reinforcement reduced to the unit of the operative width of the plate. The calculation is then easily made, the small compressive forces in the upper part of the girder left out of consideration, one obtains, assuming a constant modulus of elasticity Ec for the compressed concrete, the distance of the neutral axis :—

$$=x \frac{2 \times a \times k \times fe + d^2}{2 \times (a \times fe + d)}.$$

The distance of the centre of the compressive strains or the distance of the point of gravity from the neutral part, forming a trapezium, can be calculated as follows :—

$$y = x - \frac{d}{2} + \frac{d^2}{6 \times (2x - d)}.$$

If the centre point of the pressure is known, the compressive force D = Z as well as the strain de can be ascertained by means of the following formulæ :—

$$dc = \frac{de \times x}{a\,(k - x)}.$$

In the case of plate beams the correct calculation for their cross-sections as regards the shearing forces is just as important as the one regarding the tensile strains, and the construction of the plate beams became only possible when it was recognised that the concrete on the one part could take up a considerable shearing stress in itself, and that on the other part with a suitable reinforcement it could counteract the shearing strains. With the plates the calculation shows such small values for the shearing stress, that they can safely be taken up by the concrete itself.

With plate beams, however, special reinforcements for the shearing forces are to be added, and the calculation for the shearing strains of the stirrups and the adhesion strains becomes necessary. The calculation of the shearing strains is done in the following way :—The shearing forces appearing in the area CC'. Fig. 5 between two neighbouring cross-sections are equal to the difference of the normal forces in AC and A'C'. If we, therefore, draw the line t of the shearing strains, the shearing strains in the upper part will be equal to O and will increase up to the value T in the direction of the neutral axis. Under the assumption hitherto observed in connection with all strain calculations, namely, that the concrete should not take up any tensile strains, the shearing strains underneath the neutral axis will remain constant.

The value in rectangular cross-section can be calculated as follows :—

$$to = \frac{v}{\left(h - \frac{x}{3}\right) \times b}$$

The value

$$b \times to = \frac{v}{h - \frac{x}{3}}.$$

shows also the sum of the adhesion strains acting on the outside of the reinforcement, so that the same can also be calculated in a simple way. With the cross-section of the plate beam the distance of the tensile and compressive centre point is substituted in place of

$$\left(h - \frac{x}{3}\right)$$

It may also be mentioned that the simultaneous presence of a great bending moment the mentioned value for the shearing strain is not altered even if the tensile strength of the concrete is taken into consideration. For in concrete, subjected to great tensions, the difference between neighbouring cross-sections is zero. An increase can therefore not take place for the shearing strains in the part of the cross-section under tension.

Out of the adhesion strain the number of iron bars is calculated which must still be present on the bearer, and it is therefore evident that it will not do to assume the dimensions by the line of the maximum moments solely. If sufficient reinforcement is not given to the supports the destruction of the girder occurs through the irons being pulled out of the concrete at the bearer ends. The distance and the thickness of the stirrups are calculated out of the shearing strain; it is a rule that 43 to 72 lbs. per square inch can be taken up by the concrete and the rest falls to the stirrups. If we know that concrete is capable of following the extension of the iron, and we do not take into consideration the tensile strains in the calculations of the dimensions. This is, in my opinion, a method of calculation giving the greatest protection against the occurrence of cracks, quite apart from the absolute safety and strength which is obtained thereby. In reality the tensile strength of the concrete is naturally still present, which fact will show only slight deflections of reinforced concrete constructions under loading tests.

Further, it must be considered that in consequence of the strong and close interlocking of all parts of a ferro-concrete structure more factors take part in the bearing of the load than generally appears in the calculations, and any of the other building systems manifest it. The slight deflection can also be easily accounted for and determined beforehand.

I herewith hope I have proved to you that the above-mentioned assumptions may be accepted as really existing facts, and that statical calculations of ferro-concrete structures can be made on a similar basis as laid down here.

In conclusion, I wish to make a few general remarks: Everyone familiar with this new building system will admit that there exist a great many reinforced concrete constructions, which give great satisfaction for the purposes they are erected for, and still exercise that resistance, if the limit of the strain is reached or even exceeded, for which the structures are calculated. Considering the splendid qualities which are proved in existing structures, there should be no difficulty in erecting buildings of greater dimensions and with complicated stresses, if the formulæ employed for calculating the dimensions of the proved structures were generalized, and extended to the new contemplated purpose, and if the fundamental materials, concrete and iron were of the same quality and were worked with the same carefulness.

While iron, wood, brick buildings, etc., are liable to decay, therefore requiring frequent overhauling, reinforced concrete constructions are gaining in strength in the course of time. Not only do these buildings resist elements as moisture, temperature, etc., but also chemical reactions have no effect on them. The iron embedded in the Portland cement concrete remains perpetually unaltered, and ferro-concrete constructions can be considered as practically indestructible by any causes.

If the reinforced concrete principle is to be extensively used in building construction, there is one important fact which must not be overlooked, "we must have cheap cement." I do not mean cement of an inferior quality, but first quality cement at a lower price.

This can only be done by erecting factories in various parts of the country, and if sufficient enterprise is forthcoming, and a factory equipped with the latest modern machinery, cement could be sold in Kimberley at 50 per cent. less than the landed cost to-day.

Only quite recently I have tested samples of the raw material which have been submitted to me, and found them equal to any sample I had seen in Europe used for the manufacture of the best Portland cement. These samples were obtained from a place within one hundred miles of Kimberley, and in close proximity to the railway line.

Another reason why reinforced concrete should be used on a more extensive scale is that South Africa does not possess a producing iron industry, and every girder has to be imported.

In conclusion, I would like to express the wish that reinforced concrete may sooner or later be introduced in constructional engineering throughout this sub-continent, and that the money which is being expended by the Governments and Public Corporations, in the purchase of steel bridges and other structures, may be retained and circulated in South Africa by the adoption of the reinforced concrete system which I have been privileged to put before you.

43—AN UNDERGROUND TRAVERSE.

By A. E. Payne.

Two years ago, in a paper which the writer had the honour of reading before this Association in Johannesburg, * reference was made to the apparently simple object of measuring an angle in an underground traverse by means of a transit theodolite. The writer called attention to the care with which the simple operation should be conducted so as to justify the reliance which must later be placed on the results obtained. Since that date it has been brought home to the writer, as a member of the Commission of Examiners for Mine Surveyors' certificates, appointed by the Transvaal Government, that there is a great diversity of opinion amongst the mine surveyors of these fields as to how this operation should be best conducted.

It would seem, therefore, advisable to follow up the outline of the mine surveyors' work, as sketched in the remarks of two years ago, with a few details of some of the methods employed in conducting an underground traverse, and the subsequent calculations connected therewith.

To obtain the necessary information from an authoritative source, the writer asked the Consulting Engineers of the chief Mining Groups represented on the Witwatersrand fields to furnish him with a copy of the form of calculation, the method of procedure, and any other relative information in general use in that group. The result of this enquiry is tabulated in the following pages:—

I. Method of Procedure.

First Method.—Self-explanatory.

Second Method—(Note to Page 403).—"In the first column the station at which the instrument is set up is noted, the second and fourth columns being for angles observed. In the column marked "mean azimuth" the stations observed are noted, under which also appears the mean reading to that station. Always reading the angles from left to right, it is easy to see which is the back sight and which are foresights. The instrument is set just over 360° and set on the back sight, lower limb clamped, upper limb unclamped, and the foresight taken; upper limb unclamped, and telescope revolved end for end on its axis and set on back sight; upper limb unclamped and foresight taken, each time reading both verniers."

"The reason for setting the instrument just over 360° is to make it necessary to read the angle instead of taking it for granted that the vernier is at zero. The readings are then meaned "B" vernier over "A" vernier, and then again B A and A B, the result of which is the true mean reading. Carrying this process through all the stations sighted, and deducting the mean reading of back sight from the foresights, the true mean horizontal angle is at once obtained. The underground stations are not more than 100 feet apart, partly because of chaining and because they are afterwards useful in stope measuring."

"In levelling the collimation method is used, rail and peg level being taken at each station."

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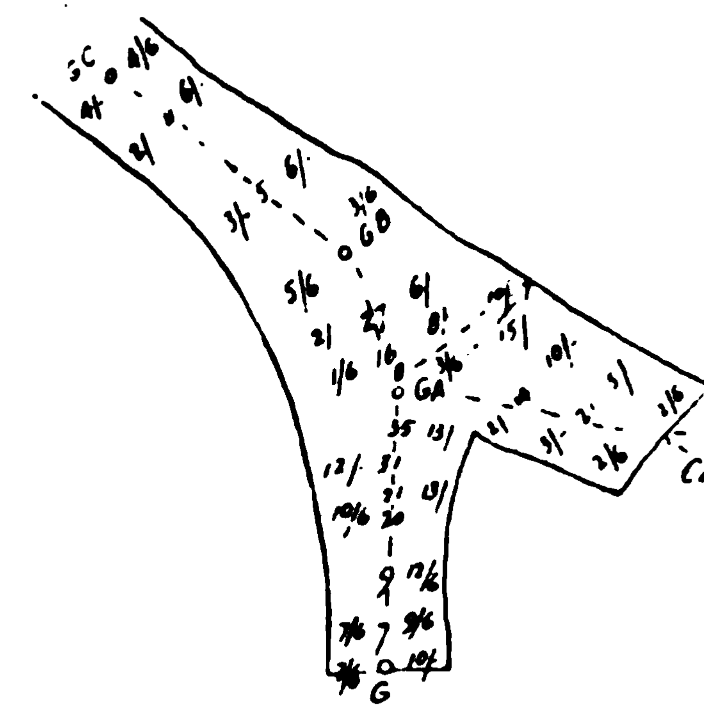
* "The Mine Surveyor and His Work in the Witwatersrand District," *vide* report of the South African Association for the Advancement of Science, Johannesburg Meeting, 1904, pp. 393–401.

I. METHOD OF PROCEDURE.

(1) = **First Method**.—0° = south; 90° = west; 180° = north; 270° = east.
[501 signifies station 501.

Station to Station.	Azimuth.	Foresight Needle.	Backsight Needle.	Measured Distance.
———— Deep, Ltd. Survey of 4th level E. Drive, South.				
Reef to face, 25th July, 1901.				
Survey party (names).				
Set instrument up on 501 B.S. to 500.				
Course 90° 46. (See vol. 2, p. 30).				
[501 to [502	89° 52′	S. 85° W.	S. 85° E.	
	Alright, see	vol. 2, p. 30.		
[502 to [520	112° 14′	N. 75° W.	N. 85° E.	V= 21·07 H=114·60 116·52′
	Vertical	angle 10° ·25′		
	Old Copper	spad in plug in roof.		
	+25′	sides	3R 3L	
	+32′	1st sd.	Boxhole	4′ R
	+38′	2nd sd.	,,	5′ R
	+52′	sides	2R	4′ L
	+67′	sides	4R	1 L
	+75′	1st sd.	Winze	3R 3L
	+80′	2nd sd.	,,	3R 3L
	+95′	Drive leaves reef in hanging		on Rt. 3′ Rt.
100′	sides	1R 5L	(No reef)	
110′	Drive enters	reef again.		
116·52′	620 sides		3R 3L	
[620 to [621	96° 55′	N. 89° W.	S. 73° E.	V= 1·82 H=25·55 25·62′
	Vertical	angle 4° ·05′		
	New copper	spad in plug in roof.		
	...10	sides	4R 2L	

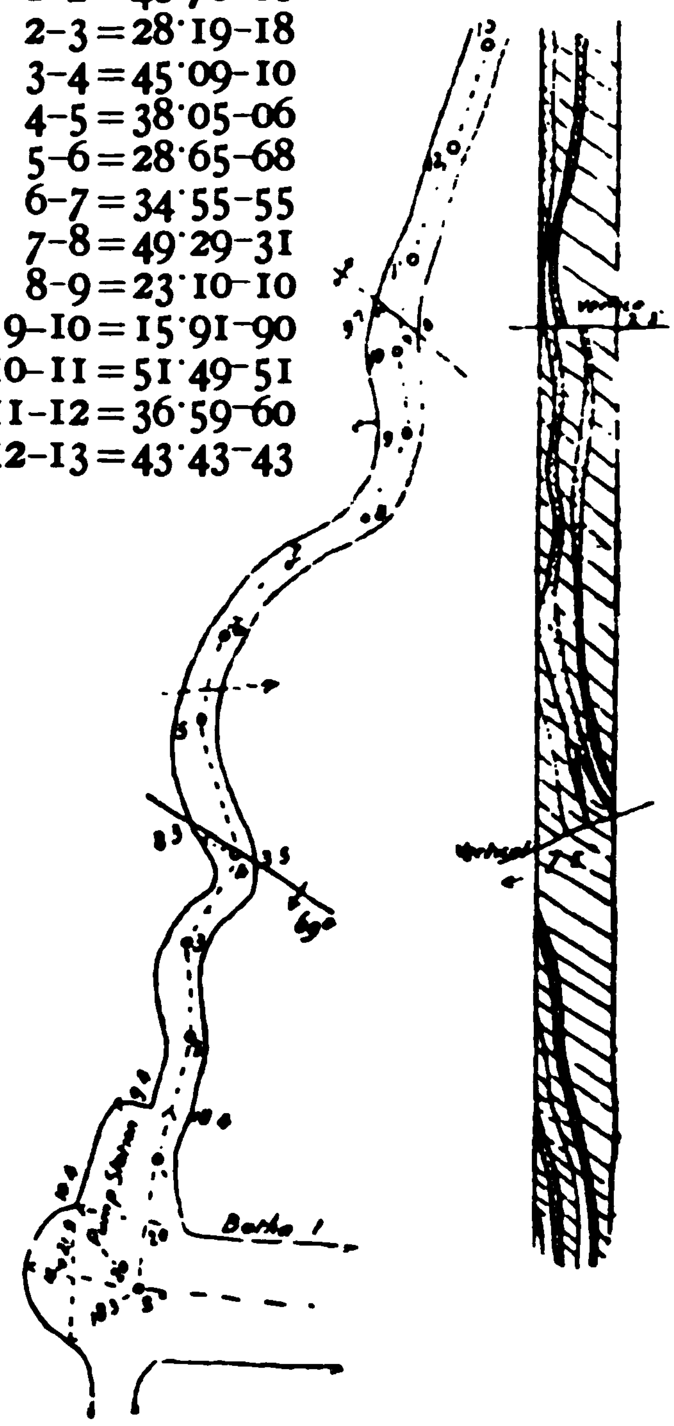
(2) = **Second Method.**—Survey of 7th level cross-cut. December 12th, 1902.

Station.	Azimuth.	Mean Azimuth.	Azimuth.	Distance.	Station.	V Angle.	Mean V Angle.	V Angle.	Distance.
G A	360° 4′30 180° 4′30	G 360° 4′30	180° 5′ 0 360° 4′ 0	36/4					
	85°36′ 0 265°35′30 35′45	G B 85°36′ 0	265°36′30 85°36′ 0 36′15	37/9¼					
	245°56′ 0 65°56′ 0 56′00	Candle 245°56′ 0	65°56′30 245°55′30 56′ 0	30/					
G B	360° 3′30 180° 2′30 3′ 0	G A 360° 3′ 0	180° 4′ 0 360° 2′ 0 3′ 0	37/9¼					
	116° 2′ 0 296° 1′30 1′45	G C 116° 2′ 0	296° 2′30 116° 2′ 0 2′15	18/0¼					
Survey of No. 1 South Shaft, 6th to 7th levels. December 4th, 1902.									
F	A 360° 5′30 B 180° 7′30 6′30 179°54′ 0 53′30	E 360° 6′45 179°53′45	B 180° 6′ 0 A 360° 7′ 0 179°53′30 54′ 0		H. of Inst. 2/11½ H. of bob. 2/11½	220°40′30 49°19′30 20′ 0 319°20′30	Dip F G 49°20 0	40°40′ 0 49°20′ 0 20′ 0 139°20′ 0	147/9
G	360° 5′30 180° 4′30 5′ 0	F 360° 5′15	180° 6′ 0 360° 5′ 0 5′30						
	185°17′30 365°16′30 17′ 0	G A 185°17′15	365°18′ 0 185°17′ 0 17′30	36/4					

(3) **Third Method.**—11th level west.

S"				
1		192·19·30		
	2	24·39· 0	192·19·30	
	1			
2		164·35· 0		
	3	329·10· 0	164·35· 0	
	2			
3		215·42· 0		
	4	71·24· 0	215·42· 0	
	3			
4		118·53·30		
	5	237·47· 0	118·53·30	
	4			
5		193·47·15		193·47·22
	6	27·35· 0	193·47·30	
	5			
6		205·10·45		205·10·48
	7	50·21·45	205·10·52	
	6			
7		207· 4·50		207· 4·55
	8	54·10· 0	207· 5· 0	
	7			
8		138·48·15		138·48·18
	9	277·36·45	138·48·22	
	8			
9		149·19·45		149·19·37
	10	298·39· 0	149·19·30	
	9			
10		224· 9·50		224·10· 0
	11	88·20·20	224·10·10	
	10			
11		156·54· 0		
	12	313·48· 0	156·54· 0	
	11			
12		176· 4·50		
	13	352·10· 0	176· 5· 0	176· 4·55

1-2=48·70-68
2-3=28·19-18
3-4=45·09-10
4-5=38·05-06
5-6=28·65-68
6-7=34·55-55
7-8=49·29-31
8-9=23·10-10
9-10=15·91-90
10-11=51·49-51
11-12=36·59-60
12-13=43·43-43



NOTE: "Elevation taken with level. Angles measured in both positions of telescope."

(4) **Fourth Method.**—At 614 S backsight on cross-cut plug 604 x.

Pos.	... ...	174·51· 0	back	—
Neg.	... ...	185· 9· 0	fore	57·78
	At 615 S.			
Pos.	... ...	169·56· 0	back	57·77
Neg.	... ...	190· 4· 0	fore	18·27
	At 616 S.			
Pos.	... ...	191·47·30	back	18·24
Neg.	... ...	168·12·30	fore	36·68
	At 617 S.			
Pos.	... ...	173· 7· 0	back	36·67
Neg.	... ...	186·53· 0		34·68
	&c.			

NOTE: "Clamp the vernier to zero and set on the back point, unclamp upper plate and sight to forward point and book the reading as "positive angle."

2. "Clamp the vernier to zero and set on the forward point, unclamp upper plate and sight to back point and book the reading as "negative angle."

3. "Tape distance to back point and book as "back distance."

4. "Tape distance to forward point and book as "forward distance."

"Repeat operation at every point of traverse."

"Distances are taped horizontally, the plumb bob being raised or lowered till approximately on a level with the instrument."

"Measure every line twice, first as a forward distance and then as a back distance; if there is any difference take the mean."

(5) **Fifth Method.**—Main Reef West Drive. 5th April, 1905.

1127 M - 1128 M = 1129 M			
	+ 160 22′	Length of plumb at	1127 = 2·46
	- 199 38′	do.	1128 = 3·76
Backsight	93 42′	do.	1129 = 2·81
	266 18′		
Distance	= 53·96	Rail level at	1127 = 6·75
		do.	1128 = 7·21
Foresight	89 05′	do.	1129 = 6.36
	270 55′		
Distance	= 65·21		

"Set up instrument at say peg 1128 M and set vernier at 0°. Clamp spindle on back sight (1127 M) and read vertical angle, say 93° 42′. Unclamp vernier and read angle 1127—1128—1129 which for convenience call **x**, also read fore vertical as 89° 05′

"Now, plunge telescope, set vernier at 0°, and clamp on foresight (1129), and again read fore vertical as 270° 55. If instrument is in adjustment the sum of both fore verticals will be

360 deg. Unclamp vernier and read angle 1129—1128—1127, for convenience called —, also read back vertical. The sum of each two readings should be 360 deg.

"Measure both back and fore distances with a steel tape, and calculate horizontal distances. The back horizontal distance at 1128 M should equal the fore horizontal distance previously obtained at 1127 M.

"Measure the length of the plumb bob at 1127, distance of instrument from peg at 1128, and length of plumb bob at 1129.

"Subtract the rail distance (or add for Government levels) from the level of survey peg, and one obtains the rail level at each peg, and thus can work out the grade of track wherever required."

(6) **Sixth Method**.- 10 S.R.E. drive. Main Shaft. 10th May, 1898.

1003 E to 1004 E.

Back distance 15·21	Forward distance 10·38		
Right L 200° 53′ 10″	Left L 159° 6′ 50″		

1004 E to 1005 E.

Back 10·38	Forward 10·15		
Right L 212° 54′ 10″	Left L 147° 5′ 50″		

1005 E to 1006 E.

Back 10·15	Forward 11·90		
Right L 151° 25′ 30″	Left L 208° 33′ 0″	-	- 1′ 30″
Doubled 302° 54′ 0″			
151° 27′ 0″ adopt.			

1006 E to 1007 E.

Back 11·90	Forward 12·63		
Right L 171° 10′ 0″	Left L 188° 49′ 0″	- 1′	
Doubled 342° 20′ 0″	Doubled 17° 40′ 0″		
171° 10′ 0″	188° 50′ 0″ adopt.		

Peg 1005 E is - distance east or west of D.M. 100 E.

SUMMARY OF RESULTS.

(*a*) *Use of Instrument.* In method (1) it is impossible to determine the use to which the instrument is placed. Checks, if made, are not recorded. Values of quadrants are completely at variance with Government Surveyors' methods in the Colony.

(2) A clear and concise method of shewing what is done.

(3) The actual readings are apparently not recorded, and angles are only taken out mentally. Check recorded.

(4) Without footnote it is impossible to determine how instrument is used. No checks of any kind are applied to eliminate errors of instrument.

(5) The actual readings are apparently not recorded; angles taken out mentally, called "positive" and "negative," after transiting instrument. Working from zero point.

(6) No indication of any check being adopted.

(*b*) *Levelling.* In method (1), conducted by use of vertical angles and no record of height of instrument, benchmarks, etc.; (2) carries on levels with azimuth readings; correct checks to angular measurements; (3), (4), and (6) use dumpy level; (5) uses angular method without sufficient check.

(*c*) *Measurements.* (2) works without decimals, which is clumsy and contrary to Law; (3) works to 3 places of decimals; (4) measures both fore and back sight, which, since he does not carry out his levels, must necessitate adjustment of all plumb bobs to height of instrument in order to serve as check on previous survey of line. This is cumbersome and unnecessary, except at start of survey, to check starting point. (5) measures fore and back distance, but also takes vertical angles, which he reduces to horizontal. Writer recommends only for inclined distances, e.g., shafts, winzes. (6) gives no indication of method of checking.

(*d*) *Other Data.* (1) and (2) adopt an off-set method for position of drive, etc.; (3) measures in reef and sketches in drive; (4), (5), and (6) apparently record no such data.

CONCLUSION.

It is hard to conceive that there is such a sad lack of uniformity in the method of procedure. The writer is of opinion that in recording work, all observations should be noted, and not merely the deductions made at the instrument and at the time. In (a), the use of the instrument, full advantage should be taken of the wonderful accuracy of a transit theodolite when used in such a manner as to eliminate errors of eccentricity, collimation, and of the standards. Opinions must vary as to (b), levelling, whether best conducted in conjunction with azimuth readings or by an independent survey with a dumpy level. The writer would not be pedantic and say one or the other should be adopted; he would point out that the former method, inasmuch as he must reduce all distances to the horizontal and so also can calculate the vertical distance before calculating the co-ordinates of any point, will enable the surveyor to be always up to date in the elevation of his benchmarks.

With regard to (c), measurements, individual practice is scarcely disclosed in a study of these six methods. It is highly probable that errors in underground traversing arise from (1) error in centering the instrument, introducing small angular errors, and (2) errors in measurement, due to the use of native assistants and the surveyor's

personal factor, e.g., variable pull on the tape, rather than any errors in the measurement of angles when the instrument is properly used.

Finally, in considering the record of other data (d), the writer is of opinion that, from the way in which the information has been forwarded to him, there is a loose appreciation of this most important part of a mine surveyor's duty. Minute and careful offsetting is, in the writer's opinion, so much waste of time. By noting the position of benchmark, in hanging of drive relative to the track, and sketching in the contour of the drive as the surveyor walks along, say in winding up his tape, a sufficiently accurate representation of the drive can be obtained on the scales of 1 : 500 or 1 : 1000, at which most plans are plotted. The intersection of any fault with the drive is noted in similar manner as the tape is being wound up, whilst the fall or rise of reef in the drive is of no import until the reef enters or leaves the drive.

We now come to:—

II. METHODS OF CALCULATION.

(1) does not feel justified in giving his method as the representative one of his group. He remarks that he uses Gurden's Traverse Tables and natural sines and co-sines as a check.

(2) gives the following:— (Square section paper.)

Fair Copy of Mean Angles read.	Bearing and Distance.	Seven Fig. Logs.		Check by Naturals.	
E—F—G	147.75	2.1695275	2.1695275	147.75	147.75
Dip and distance ...	49.20. 0	9.8140912	9.8799634	961.56	58.57
		1.9836187	2.0494909	88650	103425
Red. level G. Rail ...	1512.10	96.30 Hor.	112.07 Vert.	7387 148 88 13	7387 1182 73
				96.286	112.067
E—F 360. 6.45 179.53.45	96.30 293.22.50	1.9836187 9.9627903 1.9464090	1.9836187 9.5986115 1.5822302	96.30 9719	96.30 8693
179.47. 0 293.35.50		− 88.39	+ 38.22	86670 963 674	28890 8667 578
473.22.50 180 293		+ 55743.77 55655.38	75653.76 75691.98	86	77
				88393	38212

Fair Copy of Mean. Angle read.	Bearing and Distance.	Seven Fig. Logs.		Check by Naturals.	
——		G			
F—G	36.33	15.602654	15.602654	36.33	36.33
360. 5.15	298.34.50	99.432664	96.797856	18.78	4874
185.17.15		15.035318	12.400510	29064	14532
185.12. 0				2543	2543
293.22.50		− 31.89	+ 17.38	290	290
478.34.50		+ 55655.38	75691.98	4	14
180		55623.49	75709.36	31901	17379
——		G	A		
298					
G-GA	37.77	15.771740	15.771740	37.77	37.77
360. 4.30	204.6.20	96.111059	99.603731	4804	8219
85.36. 0		11.882799	15.375471	15108	33993
85.31.30				302	378
298.34.50		− 15.42	− 34.48	14	75
384. 6.20		+ 55623.49	+ 75709.36	15424	30
180		+ 55608.07	+ 75664.88		34476
——		G	B		
204					
GA-GB	18.03	12.559957	12.559957	18.03	18.03
360. 3. 0	140.5.20	98.072633	98.848184	6146	0767
116. 2. 0		10.632590	11.408184	10818	12621
115.59. 0				721	1082
204. 6.20		+ 11.57	− 13.83	18	126
320. 5.20		+ 55608.07	+ 75664.88	11	13829
180		+ 55619.64	75651.05	11568	
——		G	C		
140					

This is systematic, but has weak points, in the writer's opinion. The angle measured is only extracted once from the field book; the angle of direction (or bearing) is only taken down once; the addition of co-ordinates is only effected once.

(3) confuses a calculation with the record of results obtained. In other words, this is no form of calculation, and cannot be criticised as such. As a form of record it contains too much; no practical good can come from laboriously copying out forms of logarithms. The plotted traverse is useful, and gives a finished record of the detail sketches made in the field book.

(4) gives the following method:—(square section paper), South drive on leader, 6th level.

614 S—615 S 57.78	127.33.30 174.51.0	127.33.30 185.9.0	These checks are performed by traverse tables.	
	302.24.30	302.24.30		
302.24.30	1.7617775 9.9264711	1.7617775 9.7291239	48.11	30.55
	1.6882486	1.4909014	.66	.42
	- 48.78 + 13207.51	+ 30.97 + 47273.14	- 48.77	+ 30.97
615 S	+ 13158.73	+ 47304.11		
615S—616S	122.24.30 169.56. 0	122.24.30 190. 4. 0		
18.25	292.20.30	292.20.30		
	1.2612629 9.9661105	1.2612629 9.5799309	16.64	6.84
292.20.30	1.2273734	0.8411938	.23	.09
	- 16.88 + 13158.73	+ 6.93 + 47304.11	- 16.87	+ 6.93
616 S	+ 13141.85	+ 47311.04		
616S—617S 36.68	112.20.30 191.47.30	112.20.30 168.12.30		
304.8.0	304.8.0 1.5644293 9.9178908	304.8.0 1.5644293 9.7490562	29.79	20.20
	1.4823201	1.3134855	.56	.38
	- 30.36 + 13141.85	+ 20.58 + 47311.04	- 30.35	+ 20.58
617S	+ 13111.49	+ 47331.62		
617S—618S 34.68	124.8.0 173.7.0	124.8.0 186.53.0		
	297.15.0	297.15.0		
297.15.0	1.5400791 9.9489101	1.5400791 9.6607459	30.22	15.56
	1.4889892	1.2008250	.60	.31
	- 30.83 + 13111.49	+ 15.88 + 47331.62	- 30.82	+ 15.87
618S	+ 13080.66	+ 47347.50		

618S	+ 13080.66	+ 47347.50		
618S—619S	117.15.0 193.59.0	117.15.0 166.1.0		
26.01	311.14.0	311.14.0		
311.14.0	1.4151404 9.8762361	1.4151404 9.8189692	19.55	17.13
	1.2913765	1.2340196	.01	.01
	− 19.56 + 13080.66	+ 17.14 + 47347.50	− 19.56	+ 17.14
619S	+ 13061.10	+ 47364.64		
619S—620S 37.65	131.14.0 162.13.50	131.14.0 197.46.10		
	293.27.50	293.27.50		
293.27.50	1.5757650 9.9625167	1.5757650 9.6000696	33.93	14.73
	1.5382817	1.1758346	.60	.25
	− 34.54 + 13061.10	+ 14.99 + 473.64.64	− 34.53	+ 14.98
620S	+ 13026.56	+ 47379.63		
620S—621S 70.50	113.27.50 182.40.0	113.27.50 177.20.0		
296.7.50	296.7.50 1.8481891 9.9531761	296.7 50 1.8481891 9.6438651	62.84	30.83
	1.8013652	1.4920542	.45	.22
	− 63.29 + 13026.56	+ 31.05 + 47379.63	− 63.29	+ 31.05
621S	+ 12963.27	+ 47410.68		
621S—622S	116.7.50 191.58.30	116.7.50 168.1.30		
37.66 308.6.20	308.6.20 1.5758803 9.8959059	308.6.20 1,5758803 9.7903641	29·11	22.83
	1.4717862	1.3662444	.52	.41
262S	− 29.63 + 12963.22	+ 23.24 + 47410.68	− 29.63	+ 23.24
	+ 12933.64	+ 47433.92		

A footnote is added: "To guard against an error in adding or subtracting 180 degrees when changing directions from forward to back, use the following check. When a sheet of paper is full, i.e., has 8 points calculated on it, write down the first direction, and add to it the sum of all the positive angles, subtract a multiple of 360 degrees, and add or subtract 180 degrees; result should be the direction of the last line at bottom of page."

Thus: *Check at bottom of page.*

Direction at top + sum of all angles + or − 180 degs. = direction at bottom.

```
127·33·30
174·51· 0
169·56· 0
191·47·30
173· 7· 0
193·59· 0
162·13· 0
182·40· 0
191·58·30
---------
1568· 6·20
1440· =4 × 360 degs.
---------
 128
+180
---------
 308· 6·20
```

(This check is done on any scrap of paper and is not filed).

He applies a further check when starting a fresh page, thus:

Check on additions of

Co-ordinate Distances. (Northings, westings, etc.)

Totals.—Co-ordinates at top of page = co-ordinates at bottom of page.

−48·78		+30·97
16·88		6·93
30·36		20·58
30·83		15·88
19·56		17·14
34·54		14·99
63·29		31·05
29·63		23·24
− 273·87		+ 160·78
+13207·51	Top of page	+47273·14
+12933·64	Bottom of page	+47433·92

(This check is done on any scrap of paper and is not filed.)

Similar to (2), this is systematic, but fails in exactly the same particulars, viz., the mechanical check of addition and subtraction.

(5) Gives the following method:—(square section paper.)

MAIN REEF WEST DRIVE.

1128M—1129M	169·40 160·22	169·40 199·38		
	330·02	330·02		
65·20	1·8142476 9·6985321	1·8142476 9·9376764	32·4672	56·3105
	1·5127797	1·7519240	0999	1733
330° 02′ 00″	- 32·57 + 89·34	+ 56·48 + 6206·42	- 32·5671 + 89·34	+ 56·4838 + 6206·42
	+ 56·77	+ 6262·90	+ 56·77	+ 6262·90
1229M—1130M	150·02 175·23	150·02 184·36		
	325·25	325·26		
73·06	1·8636797 9·7539540	1·8636797 9·9156025	41·4351	60·1010
	1·6176337	1·7792822	0341	0·494
325° 25′ 30″	- 41·46 + 56·77	+ 60·16 + 6262·90	- 41·4692 + 56·77	+ 60·1504 + 6262·90
	+ 15·31	+ 6323·06	+ 15·30	+ 6323·05
1130M—1131M	145·25·30 157·20	145·25·30 202·40		
	302·45·30	302·45·30		
47·88	1·6801541 9·9247755	1·6801541 9·7332750	39·5214	25·4373
	1 6049296	1·4134291	·7400	4763
302° 45′ 30″	- 40·26 + 15·31	+ 25·91 + 6323·06	- 40·2614 + 15·30	+ 25·9136 + 6323·05
	- 24·95	+ 6348·97	- 24·96	+ 6348·96

The following explanation is given: "The first line on the co-ordinate sheet is the direction of 1127 M to 1128 M—180 degs.

"To this you add the plus angle and subtract the minus angle as read underground. If instrument is out of adjustment and readings do not add to 360 degrees, take mean of readings and place in first column as direction of 1128 M to 1129.

"Calculate horizontal distance, and also place in first column.

"The fourth line of sheet is log. of distance; fifth line is log. cos. and log. sine; seventh line southing and westing as obtained from logarithms; eighth line the co-ordinates of 1128 M; and the last line just above the co-ordinates of the new point 1129 M.

"The two columns on right of sheet are used for checking with traverse tables.

"The horizontal and vertical distances are worked out on a similar sheet to the co-ordinate sheet, and are kept with the co-ordinate sheets.

"All co-ordinates and elevations are copied into a strongly-bound book, which is usually kept in the office safe."

This method is systematic, but, in addition to the weak points noted in (2) and (4), he does not work out his horizontal distance on the same sheet, but does so on another.

In the writer's opinion, the calculation of data observed at any one station should be all done together in the same natural sequence as observed.

(6) gives the following form:—

Survey 10th Level, New Main S.R.E.

1003 E—1004 E	320·18·50 200·53·10	320·18·50 159· 6·50	10·38 2223	10·38 66·49
	161·12· 0	161·12· 0	3114	9342
10·38 161·12·0	1·0161973 9·5082141	1·0161973 9·9761891	207 21	414 62
	·5244114	·9923864	2	6
	+ 3·34 +665·00	− 9·82 +4818·74	+ 3·344 +665·00	− 9·824 +4818·74
1004 E	+668·34	+4808·92	+668·34	+4808·92
1004 E—1005 E	341·12· 0 212·54·10	341·12· 0 147· 5·50	10·15 63·42	10·15 8969
	194· 6·10	194· 6·10	2030	9135
10·15 194·6·10	1·0064660 9·3867879	1·0064660 9·9867091	406 30	609 91
	·3932539	·9931751	6	8
	− 2·47 +668·34	− 9·84 +4808·92	− 2·472 +668·34	− 9·843 +4808·92
1005 E	+665·87	+4799·08	+665·87	+4799·08

1005 E—1006 E	14· 6·10 151·27· 0	14· 6·10 208·33· 0	11·90 5942	11·90 3869
	165·33·10	165·33·10	2380	10710
11·90 165·33·10	1·0755470 9·3970498	1·0755470 9·9860449	476 107	714 95
	·4725968	1·0615919	6	3
	+ 2·97 +665·87	- 11·52 +4799·08	+ 2·969 +665·87	- 11·522 +4799·08
1006 E	+668·84	+4787·56	+668·84	+4787·56
1006 E—1007 E	345·33·10 171·10· 0	345·33·10 188·50· 0	12·63 593	12·63 9·19
	156·43·10	156·43·10	3789	11367
12·63 156·43·10	1·1014034 9·5968541	1·1014034 9·9631173	1137 63	126 113
	·6982575	1·0645207		
	+ 4·99 +668·84	- 11·60 +4787·56	+ 4·989 +668·84	- 11·606 +4787·56
1007 E	+673·83	+4775·96	+673·83	+4775·95

This form has the improvement of mechanical check in the addition or subtraction of co-ordinates, but is weak in the check of angular data.

CONCLUSION.

There is obviously here a much greater tendency to uniformity, which encourages the writer to believe that since all forms of procedure tend towards this one object of calculation, it (viz., such procedure) can be made more uniform. In calculation, however, there is room for greater clearness of expression. For instance, in bringing forward an angle of direction (or bearing), no one clearly indicates what line is so directing. The name for the station, the co-ordinates of which have just been calculated, might be marked more clearly. The process of calculation of one point should be separated from that for another by a well-defined space or line. These are quite minor points, but the writer considers them worthy of attention.

Further, the use of the word "bearing," and the grouping of latitudes and departures into northings, southings, eastings, and westings, should be abolished. These are relics of needle surveying. In this Colony the mine surveyor is working off an astronomical meridian, such a meridian is his north and south line; it traverses

in projection an imaginary circle of 360 degrees through the diameter joining 90 degs. and 270 degs. This line is the surveyors' north and south axis, whilst, by co-ordination, all points of survey must be referred to an origin which lies at the intersection of an east and west axis drawn at right angles to the north and south axis or to a parallel thereto. The reference of the points of survey to this origin is by means of ordinates and abscissæ, having sign values in accordance with the direction of their projection on to the axis of co-ordination. We should thus cease to speak of a line "bearing N 40 deg. E," and say that it is a line "whose angle of direction is 130 degrees." The writer maintains that this is no pedantic distinction, but is a true mathematical expression, and in accord with the practice of the Land Surveyors of this Colony, who fix the north direction as 90 degrees.

After such a free criticism of other people's methods, it would be invidious of the writer not to proffer both a method of procedure and a method of calculation. But, in criticising, the writer has in many cases made clear what he considers the best practice should be, whilst, at the same time, he recognises that he is but criticising information supplied to him, and not a method with which he has been actually in touch. Therefore, it is possible that in putting forward the following forms he may be including much which he has failed to find in the copies of the six systems included in this paper:—

I.—PROCEDURE.

21/5/06.

At 930 R. C. and L. Drive.

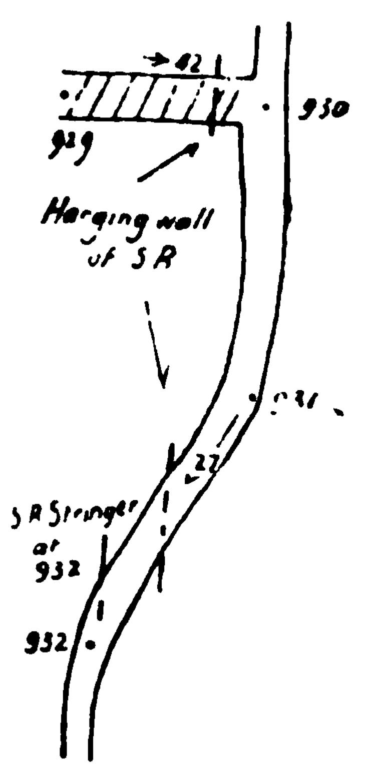
929	239 :	42 :	00 (A)	59	41	30
		42	00 (B)			
931	178 :	20 :	30	358	20	30
		20	30		20	30
Dip	89 :	4 :	00	270	56	00

Inst. 1·47
Dist. 29·24 Pb. 2·31 Tr. 6·47

At 931 L.

930	72	45	00	252	45	00
		45	00		45	00
932	257	22	30	77	22	30
		22	30		22	30
Dip	89	54	00	270	06	00

Inst. 2·45
Dist. 24·26 Pb. 1.61 Tr. 5·60



NOTE: R.C., L., etc., denotes whether station is right, right centre, centre, left centre, or left of drive, cross-cut, etc. Inst. = height of instrument below station plug in hanging of drive. Pb. = length of plumb line at foresight. Tr. = height of track from rail level to station plug at foresight. "A" "B" mean A and B verniers.

The date of survey is recorded. The instrument is clamped at any point of circle, thus avoiding wear in the clamps, etc., when always set at zero. If the booking be consecutive with the procedure of observation, there can be no mistake about which is the angle measured in the right direction. Thus, the reading at 931, being the foresight, is subsequent to the travel of the telescope from the reading at 929, being the backsight. Subtracting the first reading from the second gives the angle measured in the right-hand direction. Now, to check this, the telescope is transited, and the operations repeated. But rather than check this angle, measured in the right direction by again subtracting the first reading from the second, the writer prefers to take out the angle measured in the left direction, i.e., subtracting the second reading from the first (vide calculation), and thus ensure that the sum of the two shall equal approximately 360 degrees. All the numerical work that is required at the instrument when observing is mentally to determine that the readings, when the telescope is transited, are 180 degrees from the first readings.

II. CALCULATION.

(square section paper) 21/5/06.

Dip 930—931		0 56 00	p. 6, F.B. 29·24	XII. 930 Inst.	-432·67 - 1·47
	1·4659774 8·2118949		29·24 9261	Rise to Pb	-434·14 + 0·48
	9·6778723		2924 1754	Rise to Roof	-433·66 + 2·31
			58 26	*931*	-431·35 - 6·47
	0.48		0·4782	*931* Tr	-437·82

x 930—929	92 4 30		x 929—930	272 4 30	
	298 38 30	(931)		61 21 00	
930—931	30 43 00	30 43 10	931—930	210 43 30	
	1·4659774 9·7082804	1·4659774 9.9343363	29·24 380·15	29·24 869·58	
	1·1742587	1·4003137	14620 292 23	23392 1462 263 172	
	+ 14·93	+ 25·13	+ 14·936		
				+ 25·136	
	+ 875·24 + 890·17	- 298·43 - 273·30	+ 875·24 + 890·17	- 298·43 - 273·30	(931)

Dip 931—932	1·3848908 7·2418771	0 06 00	24·26 4712	931	-431·35 - 2·45
	9·6267679		2426 1698	At Inst.	-433·80 + 0·04
			97	At Pb.	-433·76
	0·04		0·04221		+ 1·61
				932	-432·15 - 5·60
				Tr. at *932*	-437·75

x 931—930 931—932	210 43 10 184 37 30 35 20 40	(932) 35 20 40	30 43 10 175 22 30 215 20 40		
	1·3848908 9·7622963	1·3848908 9·9115247	24·26 94875	24·26 96518	
	1·1471871	1·2964155	12130 1698 194 102	19408 243 121 142	
	+ 14·03 +890·17 +904·20	+ 19·79 -273·30 -253·51	+ 14·034 +890·17 +904·20	+ 19·788 -273·30 -253·51	(932)

NOTE: The writer prefers to do the calculations in a foolscap book, square sectional paper, rather than on loose sheets of paper.

The date and reference to page and number of field book should always precede the calculations.

x is a symbol, meaning "the angle of direction of."

x 930—929 and x 929—930 are both copied down from final calculation for 929, the two angles differing by 180 degs. By adding the right angle to the one, and subtracting the left angle from the other the new angle of direction is obtained in two ways, differing by 180 degs. The check on taking out the angles from the field book is that they add to approximately 360 degs. allowing for the errors in reading. The mean is taken out to the nearest 10 secs., the extent to which the logarithmic tables are used.

Dips are worked out first; an angle of dip of less than 1 deg. is negligible for cosine. Elevations are carried out at once by bringing forward reduced level of starting point. If it has been necessary to work out horizontal distance, then logarithm so obtained is brought

forward for calculation of latitudes and departures, the logarithmic calculations of which always decide the value in preference to decimal points of check.

The writer is of opinion that this method of calculation will ensure that mechanical check of accuracy so necessary in results of this importance. From long practice he has found that the calculation of any one point takes about ten minutes. The method of procedure takes a varying amount of time, according to the amount of accessory data the surveyor may find necessary to note down. On the average, ten minutes at any one station, is about an average time, when native assistants are hanging plumb bobs whilst surveyor is levelling the instrument.

The writer cannot conclude without hoping that, though he has made free use of information which several individual mine surveyors have supplied at the request of their Consulting Engineers, it will be felt that he is grateful for the trouble taken in forwarding this information. As several have asked that no names might be mentioned, the writer can only tender his thanks collectively to both the Consulting Engineer of the Group and the individual surveyors.

To the members of this Association his apologies are due for bringing to their notice so much that savours of text-book work. The writer feels, however, that by placing these deductions on record, the attention of many mine surveyors may be called to the want of coherence in their work, which may result in some practical good.

44—WATER RATING.

By G. W. Herdman, M.Inst.C.E.

There is much difference of opinion as to the proper method of charging consumers for water. All must have water, and must pay for it, either directly or indirectly, and, consequently, it is of some importance that the public should know for what the payment is made and how it is exacted.

It is assumed in this paper that the water is not supplied by a private money-making company. The number of these is gradually being reduced, and Waterworks for the supply of large communities are being taken over by Municipalities or Water Boards. Many of the old Companies have been compelled by Act of Parliament to limit the amount of their dividends, and if the profit is more than sufficient to pay that dividend, the consumers have to get the benefit, and the price of the water is reduced. Municipalities generally consider that the water supply is one of the first undertakings which it is their duty to control for the public benefit, and the Municipal Corporations which have recently come into being in the Transvaal have not been slow to accept their responsibilities. Many of them are now either proposing or carrying out works, and as all citizens have the double interest in the system of rating that comes to them as consumers or purchasers, on the one hand, and as voters or sellers on the other, this is a subject which Councillors must carefully look into before drawing up a new tariff.

In some towns the revenue from water not only pays all the expenses chargeable to that account, but supplies a balance for other Municipal purposes. Pretoria is an example of this. In the published accounts for the year 1904 the balance is £10,687 18s. 6d. At the same time the public health of the community is so dependent upon the water service that in *some* cases a Municipality would be justified in carrying out a water works project, even though the purely water revenue did not equal the expenditure. The deficiency would be made up by indirect returns, due to increased prosperity.

On account of this universal necessity for water, the charges for it are frequently drawn up on entirely different lines from the charges for some other public services, such as electric light, or tramways. These latter are taken as luxuries, which individuals may indulge in or not as they please. The water service is more frequently classed with drainage works, street paving, street lighting, and such like, which are necessities to all, and for which the revenue should be obtained from the citizens in as equitable a manner as possible. On that account it is sometimes considered good policy so to regulate the charges that the burden falls less heavily on the poor than on the rich. In the poorer parts of London this is so. The East London Water Works Company supplied house property by assessment, and large manufactories, taking millions of gallons of water per diem, by meter. In the latter case the rate charged was almost double that in the former. Nearly 20 per cent. of the houses supplied paid less than 10/- per annum, while the average

revenue from all house property was just over 20/- per supply per annum.

In many towns special consideration is not given to the poor or small consumers. In Portsmouth a trade consumer, who takes by meter 30,000 gallons per quarter, is charged 1/6 per 1,000 gallons; a customer who takes 500,000 gallons per quarter is charged 11½d. per 1,000 gallons, the former being 50 per cent. higher than the latter. In Germiston many customers take less than 600 gallons per month, for which they pay the minimum charge, 8/- (being 6/6 for water per 1,000 gallons and 1/6 meter rent), whilst a customer taking 4,000 gallons per month is charged 27/6. The former rate is 1/4, and the latter 8¼d. per 100 gallons, i.e., the former is about 100 per cent. higher than the latter.

It will be advisable first of all to look into the ordinary expenditure, to see what the revenue must be made to cover. The expenses may be given as :—

- Interest on Capital borrowed.
- Redemption.
- Management.
  - Secretary.
  - Accountant.
  - Collectors.
  - Stationery, etc.
- Maintenance.
  - Water Rights.
  - Rents.
  - Rates and Taxes.
  - Engineering.
  - Reservoirs.
  - Mains.
  - Pumping.
  - Filtration.

In valuing Waterworks undertakings, which already have had a long life, it is customary to consider that such a sum is being spent annually on maintenance, as will keep the works in first-class order, so that not only repairs, but also renewals, are included. The maintenance is consequently high. Depreciation and Redemption are then not considered, as the works are taken to be at any time of full value for earning revenue. A new undertaking is, however, different, and it is right that Redemption should be allowed for, as during the first few years maintenance is likely to be small. In the Pretoria published accounts, Depreciation is included, but on the Capital Expenditure interest only is paid, and not Redemption.

How the revenue to cover these expenses is to be obtained, and from whom it is to be collected, is the matter under discussion. So long as the money is obtained, it is immaterial to the Corporation from whom it comes, and the easier it is to collect the lower do the Management costs drop, and the less has to be collected. The payer

generally prefers to think of his money going for pumping or filtration rather than for clerical or office expenses.

The proportion that these different items bear to one another is of interest, and some actual cases are given in Table I., and shown diagramatically on Figure No. 1.

To obtain the necessary revenue, Corporations have different systems of charging their customers and different opinions as to who the customers are. In some cases the consumer is the customer, and is made to pay; in some cases the owner of the property supplied is charged. Payment, too, may be exacted :—

(a) According to the quantity of water used.
(b) According to the opportunities of using it.
(c) According to the value of the premises where the supply is taken, or
(d) Any combination of those systems.

Before discussing these different systems in detail, it is worth while considering who use the water, who benefit by it, and who pay for it.

1. The greatest user is generally the Municipality, which draws heavily for street water, sewer flushing, and fire extinguishing. In Johannesburg, street watering takes 30 per cent. of the whole supply, and in Pretoria 12 per cent. (see Table II. and Figure No. 2). The beneficiaries in this case are :—

(a) All inhabitants of the town, who live in more healthy surroundings on account of the Municipality's action, and

(b) All landlords, on account of the increased value and safety of their property. This Municipal water is generally paid for by a tax, which may be a general assessment rate, falling on the landlords, or a public water rate, paid partly by tenant and partly by landlord. In some cases a general charge is not made, with the result that those who pay for water pay not only for what they use, but for a share of what the Municipality uses.

2. The next users to be considered are the townspeople, the house occupiers, who use water for domestic purposes, garden watering, etc. In this case the beneficiaries are the users. The payment is made sometimes by user, sometimes by landlord. It is a common practice to charge the user in good class property, which has a valuation above a certain limit, but to charge the landlord in the case of property of lower value. It is a convenience to the seller to deal only with landlords. There are not so many bad debts, there are fewer landlords than there are householders, and consequently it is less trouble to collect the money, and the landlord may be trusted to take his equivalent out of the tenant.

3. Business people who require large quantities of water for trade purposes. This includes all cases where the amount used on any premises is greater than is required for ordinary domestic purposes. These may be looked on as wholesale purchasers, in contrast to

retail purchasers. The beneficiary here is the user, and in almost all cases he is made to pay. He is as a rule charged according to the quantity he uses, which may be recorded by meter, and payment made at a fixed rate per unit quantity, or the amount may be limited by a certain size of pipe, and a contract entered into, laying down the charge per month.

It is thus apparent that many consumers, such as tenants of small houses, lodgers and occupants of hotels, or residential flats, do not pay directly for the water they use. The relative quantity taken by these different classes of users varies in different towns.

1. PAYMENT BY RATE.

The most common method of charging for water is on an assessment basis; either a percentage on the rental, or on the valuation of the property. In Pretoria property is classed in grades rising by £250 steps to £2000, and thereafter by £2000 steps. The annual charge starts at £2 for property under £250, and increases by £1 for every step. In most cases this rate is collected from the owners —a practice which is a great saving to the Municipality.

In many British towns the rate is stated in pence per £1 of rental, and it is generally collected from the occupier of the premises. The rate is frequently divided into *public rate* and *domestic rate*, the former, or at least a portion of the former, being paid by the owner, and the latter, except in the case of property of low value, being paid by the tenant. This system shows an endeavour to make the beneficiaries pay according to the benefits they derive.

It should be noted that 1d. in the £1 public rate may bring in much more than 1d. in the £1 domestic rate. Table III. gives examples of rating in different towns.

2. PAYMENT BY OPPORTUNITIES OF USING.

Most Municipalities who charge by rate as above, have, in addition, fixed charges for certain users beyond the necessities for domestic purposes, e.g., baths, bake-houses, builder's yards, gardens, greenhouses, horses and cattle, ètc., etc. It is sometimes optional whether the fixed charge will be made, or a meter put on. Such a system is quite just, and where these extras can be looked upon as luxuries, the rate for them should be high compared to the domestic rate, which is to cover the expense of the water considered as a necessity for health, e.g., garden water must be looked on as a luxury compared with water used for household purposes.

This system is made use of in some towns where a fixed annual charge is made for the use of a pipe from the street main for the supply of a house, and an additional charge is made if a hose-pipe is used for garden watering.

In South African towns, garden watering is an important item, and the quantity used on it is frequently in excess of that used for

house purposes. It would not be unjust to put such a price on garden watering that on an average the rate paid for it would be higher than for water used in the house. If the consumer does not intend to use water on his garden, all outside taps should be removed, so that there may be no temptation. The water inspectors will know those who pay for garden water, and if they observe a garden which has no right to water looking surprisingly green, they will watch, and if they discover the irrigator at work prosecute him. A few spare meters kept to put on the pipes of consumers who are suspected of abusing their privileges will give useful information, so that occasionally an offender will be convicted. If a penalty be exacted others will take warning.

Table IV. gives the tariff in some towns.

3. PAYMENT BY THE QUANTITY CONSUMED.

It is so natural to charge for any commodity by the quantity taken, that it appears to be necessary to make out a strong case to justify any other procedure. And yet there are comparatively few towns where water is supplied solely by meter. Berlin was one of the first of these, and by 1878 the supply was given in no other way. Other towns in all parts of the world have followed the example, but in America the system has been taken up more keenly than anywhere else. The points brought out in its favour are :—

1. Each consumer is himself responsible for the amount he is charged, and consequently the payment is just.

2. Owing to all consumers having an interest in the prevention of waste, the quantity of water used is restricted, and consequently the supply of water available will go further.

There are two systems of charging by quantity. (1) The *dribble system*, where the supply-pipe is restricted in diameter, so that the discharge only amounts to a limited quantity per month. For this system cisterns are a necessity, and it is objectionable to have to draw drinking water through a cistern. The consumer thus for a certain payment has a limited quantity of water supplied in a continuous small flow. This system is used at Cape Town. (2) The *meter system*, where the quantity drawn by any customer is not restricted, but it is measured and he is charged accordingly. He is charged for the water used, and, in addition, is generally charged a rent for the meter. A minimum is fixed (say 1,000 gallons per month), which must be paid for, and thus customers have nothing to save by taking less than that quantity.

METERS.

It is presumed that the type of meter employed is one which will record accurately. Many Municipalities know to their cost that

some meters of the inferential type are apt to record low when they get old, and sometimes not to record at all when the supply is drawn very slowly. Unscrupulous customers, knowing this, will arrange to draw water continuously at a slow rate, and thus get with a low meter record a quantity which, if drawn through the meter in a short time at a rapid rate, would be recorded considerably higher. It does not do to condemn a system because it fails in a particular case where bad materials are used, but it must be borne in mind that there *are* meters on the market which are not satisfactory under all conditions, and that the customer who thinks his monthly bill too high, *can* induce the meter to record more to his liking. On that account, only positive meters will be considered.

When the property supplied is above a certain value, the occupier or consumer will probably pay. The tenant of such property, for the sake of keeping the monthly bill down, is not likely to restrict himself in the quantity of water used in the house, but he will see that there is no waste, and he will probably not give his garden the allowance it would have through an unmetered pipe.

In property of low value the owner will pay. In this case the occupier has no interest in saving, and has no reason for restricting himself. In poor class property this is possibly fortunate, as there is otherwise a danger of the quantity used being restricted beyond the limits of sanitary requirements. The meter thus fails to reduce the consumption in the case of tenants occupying property of low value.

Meters in Continental Towns.

In Berlin, Naples, Vienna, and other Continental towns, the success of the meter system is greatly due to the habits of the people, who are accustomed to living in flats. Each building contains several distinct dwellings, and 67 inhabitants per house was the average in Berlin in 1890.

In Berlin the Municipality sold the water wholesale to the landlords, who paid for it by the quantity and distributed it to the various tenants, who were the consumers, and paid for it indirectly in rent. Had the distinct dwellings of the 67 inhabitants in each block of buildings been separate, each with its own meter, there would have been probably at least 10 dwellings and 10 meters, and the meter charge of the town would have been increased tenfold, and no further saving in the water would have been effected. As it was, the meter rental was 2.37 per cent. of the revenue for water, hence it would have been 23.7 per cent., which appears excessive. It may be noted that in the year 1903-04 the Johannesburg Water Works Company's meter rental amounted to 6.25 of the water revenue, and the meter expenditure amounted to 12 per cent. of the other maintenance and management expenses. The rent charged by that Company (2/6 per mensem) does not appear to have been too high.

Meter Rent.

The chief argument against metering all service pipes is the high cost which the system involves. Table V. gives the annual charges on a positive meter for domestic use, and shows that the customer will have to pay about 3/- per month for knowing how much water he uses compared with his neighbour. If the correct rent for an inferential meter, in place of a positive one is worked out, it will be found to be not much less. The first cost will be lower, but the maintenance and depreciation will be higher. These figures may appear high, but the Rand Water Board's charges are much higher in proportion, amounting annually to over 60 per cent. of the meter cost. The question is, could not the Engineer devise a more economical method for distributing the water?

In some towns the customer is charged this meter rent, and as it is constant for a large consumer or a small, it falls heavier on the latter. Some towns, such as Johannesburg, put it into maintenance, and the customers are only charged for the water they use. This is more just to the consumer, since the "life" of a meter depends rather on the amount of work it does than on the number of years it is at work.

It is true that there are few commodities which are not sold by the quantity. Though statistics of cost, in the case of water, are generally worked out per 1000 gallons, it is manifest that the *quantity* is not the only item that controls the cost. With the exception of water-rights and filtration, almost all the expenses in waterworks are for transport. The customer pays not so much for the water as for the convenience of having it brought to his house. The cost of the water at the intake is generally a small percentage of its cost at the consumer's tap. The reservoirs, the pipes, the valves, the pumps are all to regulate the transport of the water just as much as the sidings, the lines, the stations, and the locomotives are in the case of a railway. On a railway one pays for goods per ton per mile, and would it be unreasonable to pay for water per 1000 gallons per mile? Some consumers draw their supply much nearer the intake than others, and so make use of a correspondingly less extent of piping, but they receive no consideration for this. It is a matter of policy to make no difference in charge for the distance the water is brought, and so the Rand Water Board has a uniform rate over its district, though more profit is made off some consumers than others. The Metropolitan Water Board has not yet brought in a uniform tariff for the whole district, and the old company's rates still hold.

In a gravitation scheme one can see that the expenses will not necessarily increase in the same ratio as the quantity drawn. But figures show that even where every drop is pumped, sometimes pumped twice, the increased cost of pumping by itself is by no means in proportion to the increased quantity lifted. Even the coal bill does not increase at the same rate as the quantity of water pumped

(see Figs. 3 and 4, showing statistics from Atalanta and London Companies). It is therefore not correct to say the expenses are in proportion to the quantity supplied.

When tolls were taken on the turnpike roads, an endeavour was made to charge travellers in proportion to their use of the roads. This system has been given up, and the present method of assessment is not considered unjust.

WATER CONSUMPTION.

We shall now consider how the water sent into town is used up. Towns differ so much from one another that the particular figures of one town will not represent an average, and it is not suggested that average figures can be made to apply to any individual case. A fair consumption in Britain is about 35 gallons per head per day, allocated as on Figure 5. Waste appears to be excessive, but engineers have to admit that it is difficult to keep it lower.

In 1902-03 the Johannesburg Waterworks sold 76.4 per cent. of what was pumped. In 1903-04 the Johannesburg Waterworks sold 78.7 per cent. of what was pumped. This year the Johannesburg Municipality sold about 80 per cent. of what was bought.

The point to be noted is that the metering of consumers' pipes only puts control on a certain portion of the total consumption, and this is not a very large portion. Consider the case of a town with 35 gallons per head per day consumption (which is a good average for Great Britain), and with a proper water carriage sewerage system, where the sanitary arrangements are provided with 2-gallon flush cisterns. The amount sent down the drains from these cisterns is at least 6 gallons per head per day. There is no control over this. Municipal and trade supplies may be put at 10, and waste at 8, gallons per head per day. The balance for domestic use is only 11 gallons, and this is the item on which the consumer can save. In a warm climate the amount used is much greater. Take Pretoria, for example; baths, stoep washing, garden watering, etc., raise the consumption to about 80 gallons per head per day for domestic purposes, the remaining 24 going to street watering, trade consumers, etc.

Water Consumption in United States.

The return of water used in American towns shows a consumption per head per day of anything up to 300 gallons. Consumers taking such quantities must be considered as drawing in bulk. 300 gallons per head per day for a family of six means 54,000 gallons per month, while many Germiston families are content with 600. Such figures are only accountable to English engineers by admitting that the waste is enormous. Meters have been largely adopted in

American towns, and the improvement is considerable, but the consumption seldom gets down to English figures. Where the consumption is great the relative expense of a meter is not so high, and so it is justifiable. It is surprising to read that it is intended to meter 300,000 service pipes at Philadelphia at a cost of about £1,000,000 If to that sum is added the capitalized value of the maintenance, etc., of these meters, the amount would appear to be sufficient to introduce a new supply of greater quantity than is likely to be saved by the consumers. Yet one can generally trust the Americans to calculate the cost of work before undertaking it, and where the consumption is over 200 gallons per head per day, the saving by meters may be great. Still it is very questionable if the engineers would have recommended it in the case of a town using under 50 gallons per head per day. It is interesting to note from statistics the result of metering in the United States of America. Mr. J. de Bruyn Kops, writing in the Engineering Record of July 9th, 1904, draws the following deductions :—

"1st. When a city has a consumption of less than 70 gallons per head per day, the chances are against its securing any reduction from this by metering.

2nd. Where the consumption is more than 70 gallons per head per day there is a reasonable hope of reduction by introducing meters.

3rd. About 70 gallons per head per day is the normal consumption in cities without abnormal waste.

4th. The introduction of meters does not tend to reduce the legitimate consumption, nor does it reduce the consumption to a point incompatible with perfect sanitary surroundings."

It is unfortunate that Mr. Kops does not touch on the financial side of the question, and one must keep that in view when he sums up by saying that meters are desirable for the following reasons :—

"1st. They are economical in that they stop waste.

2nd. They do not reduce the consumption to a point where unsanitary conditions arise.

3rd. They are the only equitable way of selling the water to consumers."

Waste Water.

Water supplying Corporations should feel it incumbent upon them to deliver as much water as the people can profitably use, and it should not be necessary to restrict the use so long as it is for legitimate purposes. It is admitted that some consumers seem to think that because water *is only water*, no check should be put on the quantity they draw. The use should be encouraged, but waste should be put down. *True waste* includes :—

(a) *Deliberate waste*, such as allowing fittings to remain in a state of disrepair; running water all night to prevent the pipes being burst by frost, or so as to flush the drains.

(b) *Unobserved waste*, such as is caused by faulty ball-cocks which allow cisterns to overflow, or burst pipes, from which the water escapes into the ground.

True waste does not include *unrestricted use*, such as two baths a day, scrubbing down the stoep, watering the streets, flushing sewers, etc. These sometimes consume a large quantity of water, and in the case of supply by meter would possibly be reduced, but they are not *waste*. Waste is the item to be cut down, and though the deliberate waste sometimes appears large, it is generally small compared with the unobserved waste. It is estimated that at least 60 per cent. of the waste is unobserved, and one-half of that passes through burst pipes. Consequently it seems to be false economy to take much trouble over the deliberate waste, if the unobserved waste is being neglected, and it is an unsound principle to restrict the use before checking the waste. Domestic meters will soon draw attention to the faulty ball-cocks and leaks on the consumer's pipes, but they cannot detect burst mains. It is only by a proper system of inspection that these can be found. With waste detecting district meters and night and day inspection, all waste can be discovered. All waste cannot be stopped. It is found that very soon after a district has been overhauled and put into first-class order, other sources of leakage occur, and it is only by constant supervision that the unobserved waste can be kept in check.

It is not within the province of this paper to describe waste-detecting processes in detail, but it may be of interest to observe that by means of meters—waste-detecting district meters, not consumers' meters—the cost of the work is greatly reduced. These meters shew on a diagram (Figure 6) the rate of flow day and night. If there is no unobserved waste, the night flow drops to nil. The day flow may be high, indicating unrestricted use, even when there is a low night flow, but a high night flow points to the necessity of bringing the night inspectors round with their stop keys and stethoscopes to show where the water is escaping. The day inspectors then go to the spot indicated, and opening the ground, disclose the fault. The night line indicates *waste* and this waste continues throughout the 24 hours. Its quantity can be estimated on the diagram, and compared with the quantity *used* as shown by the day line (see Figure 7).

Waste Inspectors can show all the unobserved waste that the consumers' meters fail to show, and they do not wait until the account comes in at the end of the month or the end of the quarter before pointing it out. They do nothing to restrict the use of water, and consequently are in no way antagonistic to sanitarians.

COST OF METERING.

Like most engineering questions, this ultimately comes to be one of £ s. d. Is it cheaper for the consumer to spend money on meters, which induce himself and neighbours to use water sparingly and to prevent waste, or to spend the money on waste inspection and extra

pumping, and, possibly, introducing supplies from additional sources? Some engineers of wide experience have, after due consideration, decided that it is cheaper to pump excessive quantities of water than to have a complete Waste Detecting Department. Some now recommend domestic meters, and do not pay much attention to waste inspection.

Each case must be considered by itself. The annual expenditure on domestic meters or on waste detecting must be capitalised to see how much it would allow for carrying out new works. To take an example :—

At present there are 4,000 houses in Pretoria. Allowing a meter for each, at, say, 30/ per annum, the consumers would have to pay £6,000 per annum to have the town metered. This, capitalised at 7 per cent., would amount to £85,000, at 4½ per cent. £133,000, a sum which would go far towards introducing a fresh supply to increase the amount available for the people.

In conclusion it is contended that where water is taken in bulk for trade purposes, the consumer should pay for it by meter. Where water is taken for domestic purposes in quantities under 5,000 gallons per month the meter rent is so high in proportion to the cost of the water that it would appear to be more economical to pay by rate, either on the rental or at fixed charges for opportunities of using. If the meter rent does not exceed 5 per cent. of the price of the water, it is not too much to pay for the knowledge of the quantity of water used. It is maintained that it is better for all parties to spend money on checking waste than on restricting use, and that the proper system of water rating for any town can only be decided by looking at the question from its financial side.

TABLE I.

REVENUE AND EXPENDITURE FOR DIFFERENT WATERWORKS.

(*See* Fig. 1.)

		Customers	Population Supplied	Gallons		Pence per 1,000 Gallons.					
				Average Daily Supply	Per head of Population per diem.	Nett Revenue	Interest, etc	Maintenance.	Management.	Maintenance & Management, etc.	Profit on Trading.
						d.	d.	d.	d.	d.	d.
1	London, 1901-2 (average of 8 Coys) ...		6,241,200	215,070,000	34 46	7 59		2 97	58	3 55	3·09
2	Grand Junction Company		444,000	20,222,000	45 54	7·69		3·15	66	3 81	3 49
3	East London Company ..		1,419,100	41,475,000	29·23	6 19		2 67	51	3·18	1 98
4	Manchester 1901-2 . .		1,100,000	30,276,000	27 6	6 22		1 25	1 05	2 30	4·07
5	Edinburgh		429,000	16,243,000	37 9	4 32		68	·65	1 33	3·04
6	Glasgow ,, .		1,057,800	60 043,000	56 8	2 51		35	·31	66	1·87
7	Pretoria 1904	3,600	21,600	1 500,000	69 5	12·10	4·30	2·34	1·35	7 99	4·69
8	. 1905 ...	4,000	24 000	2 500,000	104 2		2 58	2 09	·43	5·10	
9	Johannesburg Waterworks Co , 1902-3...	6,410	51,280	*1,030,000	19 8	86·84	13 12	33 12	5 59	51 83	41 70
10	,, ,, 1903-4	7,287	58,296	*1,230,000	21 1	86·92	12·48	29·18	5 44	47·10	37 27

* Water sold.

NOTE.

1, 2, 3, 4, 5 and 6 taken from Lass & Wood's London Water Company's Accounts.
7 and 8 ,, Pretoria Municipal Accounts.
9 and 10 ,, Johannesburg Water Works Company's Accounts

TABLE II.

Allocation in percentages to trade, municipal, and street watering, of the total quantity of water used in different towns. (See Fig. 2.)

	Trade.	Domestic.	Street Watering.	Total.
London	20%	80%		100%
Sheffield...	22%	78%		,,
Nottingham	32%	68%		,,
Manchester	35%	65%		,,
Derby	41%	59%		,,
Pretoria		88%	12%	,,
Johannesburg		70%	30%	,,

TABLE III. WATER RATES IN DIFFERENT TOWNS.

House of £120 Rental per annum, with Bath, 3 W.C.'s and High Service.

Town.	Charges.	Per Annum.	Per Mensem.
London (West Middlesex, 1903) ...	Rate 4%	4 16 0	
	Bath, etc., at Tariff	1 4 0	
		0 8 0	
		6 8 0	
	Less 5%	0 6 5	
		6 1 7	10/1½
Portsmouth, 1906	Rate 3½%	4 4 0	
	Bath, etc., at Tariff	0 6 0	
		4 10 0	7/6
Edinburgh, 1906	Public Rate 2d. per £1	1 0 0	
	Domestic 6½d. ,, on houses ... ,, 2d. ,, on shops	3 5 0	
		4 5 0	7/1
	Paid by Landlord, £0 10 0 ... ... ,, Tenant, 3 15 0	4 5 0	
Glasgow, 1906	Public Rate 1d. per £1	0 10 0	
	Domestic Rate 5d. per £1	2 10 0	
		3 0 0	5/-
Pretoria, 1906	(House valued at £1,200) Water Rate	6 0 0	10/-
Johannesburg (Waterworks Co., 1903)	Water, 10/- per 1000 gals. (say 3000 gals. per mensem)	18 0 0	
	Meter Rent, 2/6 per mensem	1 10 0	
		19 10 0	32/6
Johannesburg (Municipality, 1906) ...	Water, 6/- per 1000 gals. (say 3000 gals. per mensem)	10 16 0	18/-

TABLE IV. TARIFF OF EXTRA CHARGES FOR WATER IN DIFFERENT TOWNS.

Pretoria	Garden, for each 7,000 square feet	5/- per Quarter.
Edinburgh	Aerated Water Manufacturers	42/- per annum.
	Chemists	6d. per £1 on annual rental.
	Dairies	4d. „
	Fishmongers	1/- „
	Greenhouses, from	5/- per annum.
	Horses, each	6/6 „
	Tennis Grounds, each Court	10/6 „
	Watering Trough for horses	52/- „
Glasgow	Hose Pipe, from	10/- „
	Bowling Greens, each member	6d. „
	Gardens, per rood	5/- „
	Horses, each	2/- „
	Steam Boilers, from	20/- „
Portsmouth	Baths for private use, each	9d. per Quarter.
	Carriages, 2 wheels	1/- „
	„ 4 „	1/6 „
	Garden, watering by water pot, per 100 square yards	1/- „
	„ hose	By meter.
	Hairdressers, each shampooing basin	1/- per Quarter.
	Inns, 25 per cent. in addition to usual rental rates	
	Water Closets—for more than one in dwelling house	9d. „

TABLE V.

APPROXIMATE COST OF DOMESTIC WATER METER IN THE TRANSVAAL.

(Meter of Positive type ½" dia.)

Capital Cost, Meter, Surface Box, Fixing, etc. £6 0 0

Life ... 7 years.

ANNUAL COST.

Interest on Capital	5%	£0 6 0
Depreciation	14%	0 16 9
Maintenance	5%	0 6 0
Reading and Extra Clerical Work ...	4%	0 4 9
	28%	£1 13 6

CAPITALISED VALUE

of £1 13 6	@ 7%	...	£24
,,	,, 4½%	...	£33

LIST OF FIGURES.

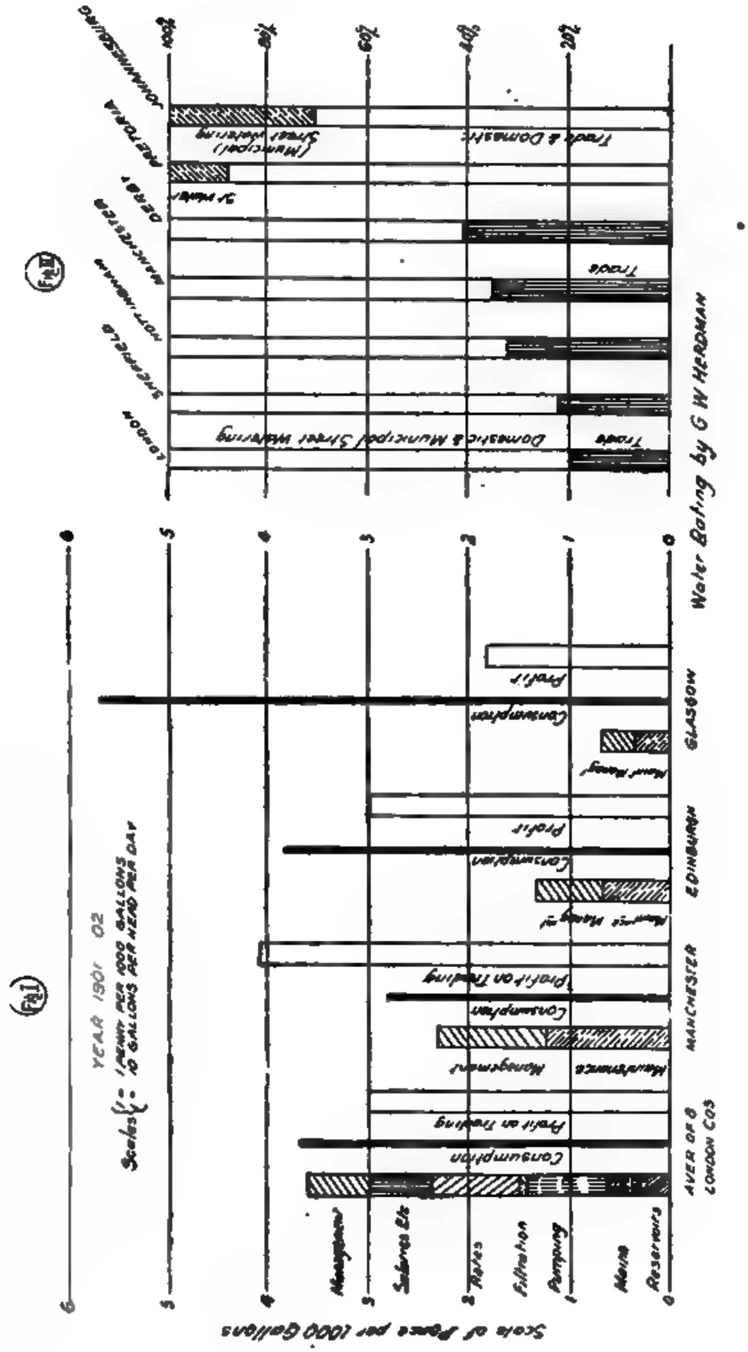
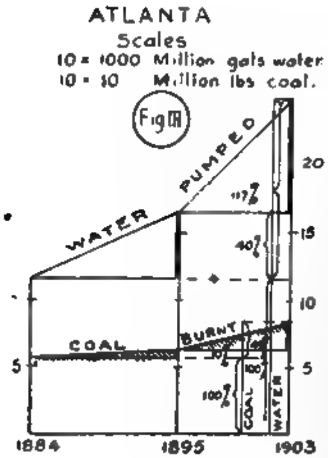


Fig I
YEAR 1901 02
Scales { 1 = 1 PENNY PER 1000 GALLONS
1 = 10 GALLONS PER HEAD PER DAY
Scale of Pence per 1000 Gallons
Management
Salaries Etc
Rates
Filtration
Pumping
Mains
Reservoirs
Consumption
Profit on Trading
Maintenance
Profit
AVER OF 8 LONDON COS
MANCHESTER
EDINBURGH
GLASGOW
Fig II
Trade
Domestic & Municipal Street Watering
Trade & Domestic
(Municipal) Street Watering
LONDON
PRETORIA
JOHANNESBURG
100%
80%
60%
40%
20%
Water Rating by G W HERDMAN



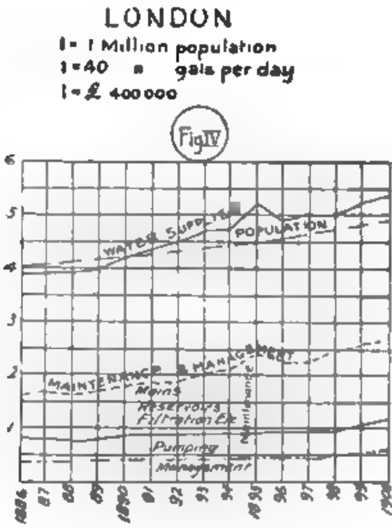
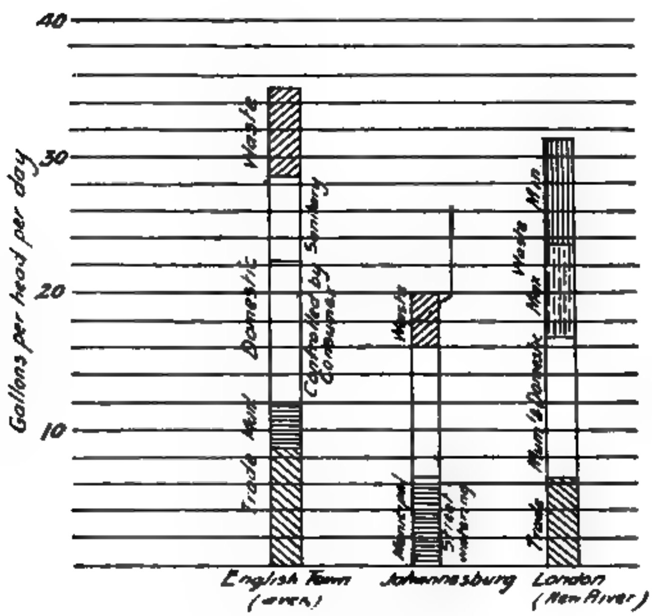


Fig V.



Water Rating by C. W. HERDMAN

Fig. VI

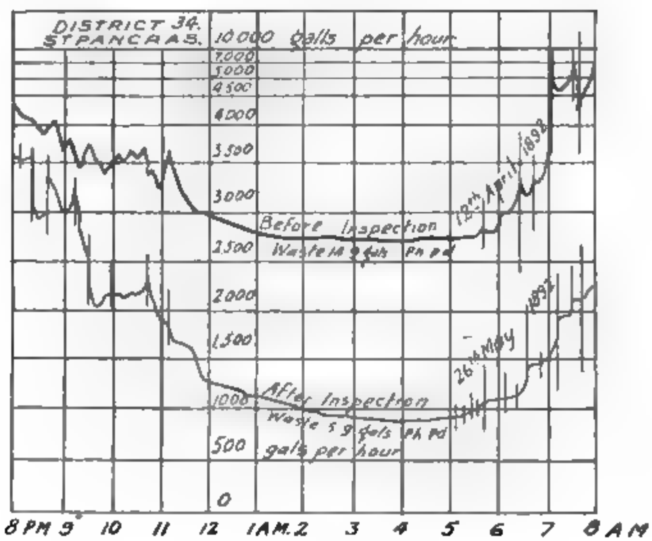
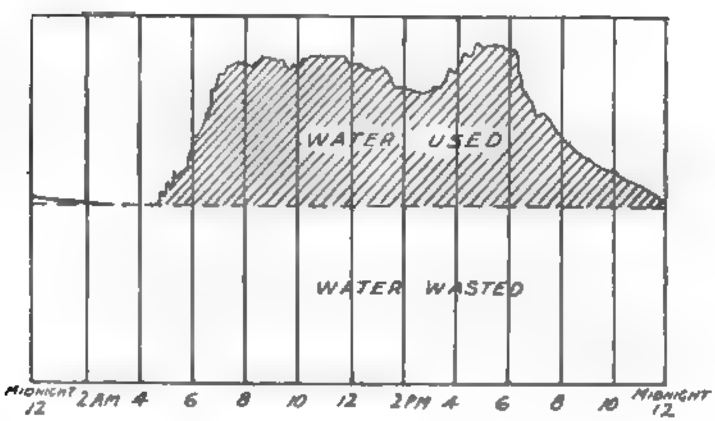


Fig. VII



Water Rating by G W HERDMAN

45—IRRIGATION IN EGYPT AND IN SOUTH AFRICA.

By F A. Hurley, F.C.H., A.M.I.C.E.

So much has been written of late years about Egypt and the Nile, that it is safe to assume that it is now a matter of common knowledge that the Nile has been the creative agency by which the land of the Pharoahs has been evolved, and is almost the sole means by which life is sustained in a country that, without it, would be as barren and uninhabitable as the surrounding desert.

Since the overthrow of the Khalifa at the battle of Omdurman in 1899, much has been learnt about the basin of the Upper Nile that was previously unknown, and any thorough description of the irrigation question in Egypt at the present day, involves a consideration of the whole river from its sources at the Great Lakes in Central Africa and Abyssinia to the sea. Even the most meagre description of the river would, however, require much more space than is usually considered ample for a single paper. The historical development of irrigation in Egypt, moreover, took place in Egypt proper; that which depends on the Upper Nile is only in the course of development at the present day.

It is proposed to describe the irrigation system of the country and its development more from the aspect of the political economist than from that of the Engineer, and therefore no attempt is made here to deal with the general questions of the Nile. The present paper deals only with irrigation in Egypt proper, that is, that part of the Nile basin between the first cataract at Assouan and the Mediterranean Sea. In writing it, the author has drawn liberally and sometimes verbatim on most of the literature that has appeared on the subject, notably:—

The Delta Barrage, by Sir H. Brown.

England in Egypt, by Lord Milner.

Egyptian Irrigation, by Sir W. Willcocks.

Administration Reports of the Egyptian Public Works Department.

From Assouan to Cairo the Nile flows in a narrow valley, flanked, north of Luxor (the ancient Thebes), by high cliffs of white limestone, from the tops of which the true desert extends east and west. Between the foot of the cliffs and the actual channel of the river lie, first, a narrow strip of desert, and then a belt of cultivated soil which has been deposited by the overflowing of the Nile during many thousands of years.

At Cairo the cliffs recede from the river, and the valley opens out into the broad deltaic formation of Lower Egypt; the country between Cairo and Assouan being known as Upper Egypt. A few miles north of Cairo the Nile bifurcates into two main branches, called, from the names of the towns at their mouths, the Damietta and Rosetta branches.

It is almost needless to say that, as the cultivable land of Egypt has been formed by a continuous deposit from the Nile as it slopes away from the river to the foot of the desert hills.

Situated in one of the largest rainless areas in the world, the climate of Egypt, except the northern margin of the Delta, is that of the great desert area of North-East Africa, the rainfall being extremely small, and occurring mostly as occasional thunderstorms. Along the Mediterranean coast there is a considerable rainfall in the winter months, but this only extends for a short distance southwards, and at Cairo ten or twelve rainy days in a year is probably the average. South of this the amount decreases rapidly, and from Cairo to Luxor, and in the neighbouring deserts, showers on one or two days, and a very occasional thunderstorm, represent probably all that falls in an average year.

South of Cairo no regular rainfall observations have been made, but the following table gives the average rainfall for six places north of Cairo :—

Place.	Rainfall in inches per annum.
Alexandria	8·26
Port Said	3·5
Ismailia	2·12
Suez	1·10
Cairo	1·06

It will be evident that the rainfall in Egypt is, for agricultural purposes, practically valueless, and that everything depends on the water of the Nile, derived from rainfall on the upper part of its catchment area. The total area drained by the river is about 1,200,000 square miles, on which the total mean annual rainfall is about 29 inches. The heaviest rainfall occurs about Lake Victoria and Albert and about Lado and the upper halves of the Saubat, Blue Nile and Atbara, and may be taken as about 59 inches per annum. In the Eastern half of the Gazelle river, the lower half of the Saubat and middle third of the Atbara it is about 39 inches. The Western half of the Gazelle river has probably about 19 inches per annum, while the Arab river and the tail portion of the White and Blue Niles, and the Atbara cannot have more than about 10 inches. From Berber northwards the country is practically rainless.

In the great lake region the rainy season lasts from February to November, with one maximum in April and another in October. At Lado the rain continues from April to November, with a maximum in August. August is the centre of heavy rainfall everywhere, except at the great lakes. It takes 90 days for the water in low supply to reach the sea from these lakes, while in flood it takes 50 days.

Owing to the variable periodicity of the rainfall over its catchment, the floods in the Nile are neither so sudden nor so intense as might be expected from the extent of the catchment area. The Great Lake and the expanse of swampy "Sudd" south of Fashoda act as regulators in reducing the severity of the flood in Egypt.

The Nile, nevertheless, behaves in much the same manner as any other storm-fed river. At Cairo the average minimum discharge is about 12,000 cubic feet per second, and is attained about the

middle of June; the river rises slowly through July and fairly quickly in August, and reaches the average maximum discharge of about 268,000 cubic feet per second about the beginning of October. Through October the Nile at Cairo is practically stationary, and falls rapidly in November, and continues to decrease until the arrival of the next year's floods.

In order that the Nile may exercise its powers of sustaining life and assisting plant growth, there are certain physical conditions that must exist; and these conditions are that the relative levels of land and water should be such that the water may flow over the surface of the land. Such conditions exist naturally at certain places in time of flood. When they do not naturally exist there is no active life, unless the necessary conditions are produced artifically by engineering works. Such works, of a primitive nature, resulting in the practice of irrigation, have existed from pre-historic times. Prior to 1805 the whole of Egypt was irrigated by what is known as the basin system; that is, by inundation, and depended on the height of the flood for its water supply. The country was traversed by dykes running more or less at right angles to the river, starting from its bank, and reaching the desert. A dyke running parallel with the river along its bank enclosed the basin on its river side, while the desert usually formed the fourth side. Almost all the basins had special canals leading directly into them the floods charged with alluvium, and they also possessed escapes which allowed the water, after it had deposited its alluvium, and stood some forty days on the land, to flow back to the river. On the mud thus produced the crops were sown, and received no further watering.

Certain basins that are at too high an elevation to be flooded naturally directly from the river, receive their water from basins upstream of them. By passing water from basin to basin it is possible to lead water parallel to the river at a flatter slope than that of the Nile, and thus to reach land that could not otherwise be flooded.

Under the basin system of irrigation, winter crops only, such as barley, wheat, beans and clover are grown on the lands from which the Nile flood had retired after watering them. During the reign of Mehemet Ali, however, who became Viceroy of Egypt in 1805, the development of cotton cultivation in Lower Egypt necessitated a radical change in the whole irrigation system. This crop could not be grown under the basin system, as it requires to be protected from inundation, and must be planted and irrigated before the Nile begins to rise. It became necessary to embank the branches of the river, which had previously found its way to the sea through the basins and minor channels, and to dig deep canals to bring the low-level water of the summer Nile to the crops, which were then irrigated by means of pumps. To keep the Nile bank in such repair that they could resist high floods, and to dig and clear the canals so that they should be deep enough to flow at Low Nile, was a very heavy tax on the country, and it was necessary to have recourse to some more scientific method for obtaining and distributing water.

M. Linant, who was then in charge of the irrigation of Upper Egypt, proposed the construction across the head of each branch of the Nile in Lower Egypt of a regulating barrage to give control over the distribution of the water between the two branches in summer, and to leave a free passage for the river during flood. A Commission, which M. Linant asked for, was called together to study the Barrage Project, and was composed of an Architect, the Chief Engineer of the Delta, the Director of the School of Engineering, a retired boatman in the confidence of the Viceroy, all of the foregoing being Egyptians. To them were added two English Engineers, a foreign Engineer who had studied in England, two French Commandants of Artillery, and a French Mining Engineer.

It is a matter for surprise that the Commission divided into two camps only. One section proposed the construction of solid weirs, over which the flood should pass, while the alternative project formulated by M. Linant was to construct Barrages across the two branches as near as possible to the head of the Delta. They were to be regulators capable of raising, during summer, the water level upstream of them to the height required to supply the main feeder canals, which would take off from the river upstream of the Barrage and irrigate all Lower Egypt. During flood the regulating apparatus was to be removed. This project, which was by far the more suitable of the two proposed, received the Viceroy's approval, and the excavation for it was commenced in 1833 by forced labour. The work went on fairly well till 1835, when a visitation of the plague caused its suspension.

The preparation of the project, however, progressed, and in July, 1835, M. Linant presented the designs and estimates of the Barrage complete for approval. By this time the plague had left, but the work did not recover, the numbers of the labourers diminished, and materials ceased to arrive. Mehemet Ali, moreover, had grown tired of the Barrage, and appointed a Commission of 16 members to enquire into the question of the desirability of such structures. In spite of a more or less open hint as to the finding that he desired, the Commission decided in favour of the Barrage, as projected by M. Linant. Notwithstanding the recommendation contained in the Report of the Commission, the Viceroy replied officially to the Minister of Public Works that the Commission might be perfectly right, but that he did not want Barrages. The works were accordingly stopped.

A few years later, in 1842, Monsieur Mougel arrived in Egypt to construct the graving dock at Alexandria, and he proposed to Mehemet Ali another system of carrying out the construction of the Barrages. His proposal received the Viceroy's approval, and after many interruptions and stoppages, due to the fancies of the rulers that succeeded Mehemet Ali, the work was officially declared complete in 1861. The cost, exclusive of the value of the forced labour, is said to have been £1,800,000.

On account, however, of the manner in which the construction of the work had been interfered with, the work of the foundation was

disgracefully "scamped," and the Barrage was found to be useless. The work was then inspected and reported on by various engineers, and the proposals for its repair were submitted, but nothing was done.

During all this time Lower Egypt was being gradually covered with a network of deep canals leading from the Nile, laid out on no scientific principles whatsoever; private interest had been the ruling principle of their construction.

These conditions entailed enormous wastage of water on one district, and impossibility of obtaining it in another. No water law existed; the ownership of the Nile—a river much too large to be exploited by any private person, has never been disputed; it has always been regarded as public property. Under the old basin system of irrigation the need for any water law was not felt; when the rise of the Nile occurred it was always in sufficient volume to inundate all the land that was reached by its level. If the flood did not rise to the level required to inundate the land, no legislation could assist to water it. The only trace of legislation on the subject was that dealing with the taxation of land. All land in Egypt paid an annual tax, but if the Nile flood did not rise to the level required to inundate any piece of land, the tax on this land was "ipso facto" remitted. The land tax was therefore, in a sense, a water rate, and this condition exists to the present day. Under the canal system introduced during Mehemet Ali's reign, no proper control of water was practiced, and the greatest irregularity prevailed; the largest landowners and the ruling powers were the "Pashas." It is fairly safe to assume that, when water was scarce, the lands of the "Pasha" suffered least from want of it.

This unsatisfactory condition of affairs continued until the revolt under Arabi Pasha, and the subsequent occupation of Egypt by the British. The country, with all its assets mortgaged to their full value by the extravagances of Ismail Pasha, stood then on the verge of bankruptcy, and obviously the first step to be taken to retrieve its fortunes was to place irrigation, on which agriculture, the sole source of wealth, depended, on a satisfactory footing.

Sir Colin Scott Moncrieff was summoned in 1883 to take charge of the irrigation of the country, and found Upper Egypt irrigated under the old basin system, a complicated system of canals in Lower Egypt, a Barrage across the Nile incapable of fulfilling the functions for which it was designed, and, worse still, intimately interwoven with these blunders a great number of vested rights. In his first report, Sir Colin wrote "Egypt was no 'tabula rasa' on which to lay down the most perfect canal systems, but a country where very life depended on a fully-developed but very bad system." Among the first works undertaken was the "restoration" of the Barrage officially completed in 1861. When Sir Colin started the idea of repairing the Barrages, he was good-naturedly forgiven for his ignorance of the country natural in a foreigner! A favourite Egyptian excuse for escaping the trouble of improvements. The

work, however, was undertaken, and the foundations and superstructure patched up so as to be fairly secure when subject to a load of about 13 feet of water. It was completed in 1890 at a cost of about £460,000. Money had been borrowed and spent freely, on the clearing of old canals. Lines of irrigation were disentangled from lines of drainage, and the whole complicated system was, as far as possible for the purpose, remodelled. When it is stated that the yield of the cotton crop alone in Lower Egypt between the years 1890 and 1900 amounted to over 58,000,000 kantars, equivalent, at a very moderate estimate, to a money value of £100,000,000, it will be evident that the work done and the sums expended have produced no contemptible return.

Although the first object of irrigation engineers in Egypt was to remodel the Barrage, and to alter and amend the existing canals so as to economise water and improve irrigation from them, the larger question of the development of the country, was not lost sight of.

At the time of the restoration of the Barrage, two systems of irrigation were practised side by side in Egypt. The ancient or basin system was employed in nearly all of Upper Egypt, and the modern or perennial system throughout Lower Egypt. The perennial system, applied to suitable lands, is more profitable than the basin system, but depends on the summer supply of the Nile, which is both limited and irregular in quantity. Basin irrigation depends on the flood, which is practically unlimited, and very fairly regular in quantity.

In Mehemit Ali's time the great preoccupation of the Government was the pressing on of the cultivation of cotton, and as the crop needed perennial irrigation, the securing of an abundant supply of water all the year round was the problem of the day.

M. Linant recommended a site in Upper Egypt for a weir and canal head, but the failure of the Barrage discouraged the Government from undertaking new works, and the question dropped.

In 1880 Count de la Motte took up the question of reservoirs, and proposed a dam at Gebel Silsila and a reservoir to the south of it. The works were to have cost £4,000,000, and the reservoir was to have contained 247,000 million cubic feet. As a counter project, Mr. Cope Whitehouse, an American gentleman, in 1882 suggested utilising the Wady Rayan, a depression in the western desert. Financial difficulties and the supposed failure of the Barrage prevented the Egyptian Government from seriously considering the question of a reservoir for supplementing the summer discharge of the Nile, as it had insufficient means of utilising the supply then existing. The subsequent success of the Barrage gave new life to the question.

It was naturally the object to ensure a continual supply of water to Lower Egypt, and to replace basin irrigation in Upper Egypt by the more profitable perennial system.

There were, roughly, about 1,732,000 acres under basin irrigation in Upper Egypt, and about 587,000 acres perennially irrigated

in that district. In lower Egypt the area of the tract capable of being perennially irrigated was about 3,930,000 acres.

Of the total area of about 6,250,000 acres, 4,130,000 had a rental of over £20,000,000, and 2,120,000 a rental of under £2,000,000. Practically one-third of Egypt was undeveloped. Moreover, nearly all the undeveloped land lay in the tracts under perennial irrigation. Now the discharge naturally required for the existing perennial irrigated lands in Upper and Lower Egypt, to say nothing at all of the undeveloped land which was capable of development under perennial irrigation, given a sufficiency of water, was about 17,650 cubic feet per second.

In 1803	the available Nile discharge in summer was	9,890 cubic feet per second.
„ 1885	„ „ „ „ „ „	12,360 cubic feet per second.
„ 1889	„ „ „ „ „ „	8,120 cubic feet per second.
„ 1890	„ „ „ „ „ „	9,890 cubic feet per second.
„ 1891	„ „ „ „ „ „	14·120 cubic feet per second.
„ 1892	„ „ „ „ „ „	11,650 cubic feet per second.

while in six other years the discharge was under 15,890 cubic feet per second. The critical period is between May 1st and July 15th, or for a period of 75 days, during the whole of which period a minimum discharge of 17,650 cubic feet per second should be ensured for the tract then under perennial irrigation.

It was obviously necessary for the further development of Egypt and for insurance of existing irrigation, that some of the flood water, the greater part of which runs unused to the sea, should be conserved and utilised to supplement the natural discharge of the Nile when it falls below the quantity desired. Colonel Western was deputed to give shape to the suggestions of Mr. Cope Whitehouse, to make plans of the Wady Rayan and the deserts between it and the Nile, to find out the capacity of the reservoir, and to see if it could be utilised. Plans and estimates were prepared, but, mainly owing to differences of opinion among the officers of the Irrigation Department as to the feasibility of carrying out the project, the question was for the time shelved.

Mr. Willcocks (now Sir W. Willcocks, K.C.M.G.) was occupied in studying the other project of Count de la Motte for reservoirs in Nubia, but on its being unfavourably reported on, in 1889 Mr. Prompt, a member of the Egyptian Railway Board, suggested utilising the trough of the Nile itself for a reservoir, in the absence of the low plains that did not exist.

By this time the Barrage repairs were almost complete, and Mr. Willcocks was appointed to study the question of reservoirs anew. The preliminary studies and the preparation of the projects occupied the four years from 1890 to 1893.

The several projects were submitted to Mr. (now Sir William) Garstin, Under-Secretary of State, who reviewed them in a note, giving his opinion generally in favour of a dam site at the Assouan Cataract. He, however, suggested, seeing the magnitude and exceptional nature of the work, that before coming to a final decision, the Government should take the advice of a Commission, composed of well known engineers. The projects were accordingly submitted to a Commission composed of Sir Benjamin Baker, Monsieur Auguste Boulé, and Signor Giacomo Torricelli, who met in Cairo in 1894. As a result of their investigations, it was decided to construct a dam to hold up water to M.S.L. 374 feet at the site recommended by Mr. Willcocks—viz., across the head of the Assouan Cataract to the north of Philæ Island.

The construction of the dam at a height of 374 feet above mean sea-level involved the submersion of the Philæ Temple, and stormy protests were lodged against the scheme by the principal Archæological Societies of Europe.

The project was consequently reconsidered, and Mr. Garstin eventually proposed a modified scheme, reducing the height of the dam by about 26 feet, so that water should only be held up to M.S.L. 348. This involved the reduction of the amount of water stored, but left the principal temple free from submersion. Mr. Willcocks then proceeded to prepare a revised project for a dam to hold up water to this level at the Assouan site, and submitted it in 1895.

As the lowest water level on the downstream side of the dam is at M.S.L. 282.0, the greatest head of water on the dam is 66 feet. The storage capacity of the reservoir is about 37,500 million cubic feet. It is filled between November and March, when there is comparatively little silt in the Nile water, and when the water in the river is in excess of that required for irrigation and discharged in May, June and July in order to supplement the discharge of the Nile during those months. The flood is discharged by means of 180 sluices through the masonry dam. In order to put the perennial irrigation of Upper Egypt on a sure footing, and to enable it to take its share of the Assouan reservoir water, it was necessary to provide for the construction of a Barrage, similar in principle to the original one at Cairo, across the Nile downstream of a canal which takes off from the Nile at Assiout. In flood time the Assiout Barrage is not ordinarily used; in summer, however, with a maximum depth of water on its upstream side of 15 feet, it may be called on to hold up 8¼ feet, so as to direct water at a level higher than the natural one into the canal mentioned above.

Both these works were let out to contract to Messrs. J. Aird & Co., in 1898, and were finished and inaugurated on 10th December, 1902. The total cost of the two works was about £3,400,000.

It may be here mentioned that the first use that the Assiout Barrage was put to was one for which it had not originally been intended, namely, the regulation of flood. The work was practically

completed in the middle of 1902, and throughout August and the early part of September of that year the river levels were unprecedently bad, and considerable anxiety prevailed in Upper Egypt regarding the irrigation of the basin lands. In some places the situation became so serious, as the proper time for sowing crops was nearly past, that it was decided to close the new Assiout Barrage on the 15th August. The result was to raise the water level upstream of it some 5 feet, and, by forcing the water into the canals feeding some of the basins, to inundate tracts, the land tax on which would have otherwise been remitted. Mr. Webb, the Director-General of Reservoirs, stated: "It is very difficult to estimate accurately the money value of the benefits gained during the flood from the construction of this Barrage; but it may be safely assumed that the direct and indirect gain was not less than £E. 600,000 * The cost of the Barrage was £E. 720,000. It will therefore be seen that the works practically repaid their cost in the first year after their completion."

The problem of providing stored water for Egypt has not, however, been solved by the construction of the Assouan dam. In order to ensure the irrigation of existing perennially irrigated tracts, a quantity of stored water of 70,000 million cubic feet is required. The lowering of the Assouan dam, in deference to the wishes of Archæologists, reduced the quantity that could be stored from 70,000 million cubic feet to 37,500 million cubic feet—a little more than half that originally estimated for. For its full development, Egypt requires 200,000 million cubic feet of stored water, and where all this is to come from is the problem at present. Various proposals for providing extra storage have been made. It is unlikely that a proposal to heighten the existing dam at Assouan would be entertained, nor would even this provide for the storage of the desired quantity of water. The old proposal to utilise the Wady Rayan has been mooted. Were Egypt alone in question, it would perhaps be possible to obtain the required quantity of water by building works at the third or fourth cataract in the Soudan. The prosperity of Egypt is now, however, closely allied with that of the Soudan, and such expensive works must in future be designed to benefit the Soudan as well as Egypt. It is, then, probable that the solution will be found eventually by damming the outlet from Victoria Nyanza, so as to raise its level and conserve water in it. This, however, is a problem much too large to be discussed in the present paper.

While investigations regarding the storage of water were proceeding, it was recognised that the head of water to which the Barrage below Cairo could be safely subjected was insufficient. During the summer, when all the discharge of the Nile must be diverted into canals taking off upstream of the Barrage, the regulating gates are tightly closed and caulked. When, about the end of June the first effects of the flood begins to be felt, the level of water

* £E = Egyptian Pound = £1 0s. 6d. (approx.).

upstream of the Barrage is allowed to rise till the head on the work reaches the safe limit. This level is then maintained by gradually opening the gates as the flood discharge increases until all the gates are fully open; the subsequent rise above this level follows the natural rise of the Nile. It thus happened that, although the demands for water increase greatly at this period, from about the end of July until such time as the gates are fully open and the upstream level at the Barrage begins to rise with the natural rise of the river, which usually happens about the end of August, the discharge into the canals cannot be increased, although a large quantity of water is running to waste down both branches of the Nile. It was obvious that, under these circumstances, the work could not properly take advantage of the water stored in the Assouan reservoir, unless that reservoir could supply enough water to bring the Nile at Cairo into a condition of flood. This it could not do.

Further expensive operations on the foundations of the work were considered undesirable, and Sir Hanbury Brown conceived the idea of constructing solid submergable weirs downstream of the Barrage, which, by maintaining a constant back pressure of water on it, would enable the upstream level of water to be raised above what had been formerly possible, without imposing any increased strain on the structure. This work was commenced in 1898, and finished in 1901. By the completion of these weirs, which enable the old Barrage (originally projected in 1833) to take full advantage of the arrival of the flood, and of the Assouan dam, which, to some extent, supplies the deficiencies of the summer discharge of the Nile, but cannot alter the date or character of its flood in any way, the perennial irrigation of Lower Egypt may be said, after 100 years, to be more or less assured.

During the construction of the large works above referred to, a third Barrage was built across the Damietta branch of the Nile, near the town of Zifta, about half-way between Cairo and the sea. Although it is a work of considerable magnitude, its functions relate more to the better distribution of water to the northern half of Lower Egypt than to the general management of the Nile, and, consequently, it is of comparatively little consequence in the general question.

The work of the Irrigation Engineers in Egypt is not, however, confined to the preparation and construction of large projects. The investigations of them occupied one or two of the senior officers of the staff, while the construction was undertaken by a special staff engaged temporarily under one of the senior officers of the Department.

The every-day duties of the staff were to improve and remodel the canal system under their charge with due regard to the extra supply of water which would be available eventually from the large projects, to see that water was distributed fairly in proportion of the areas under cultivation, and to advise the civil authorities regarding disputes about water. A law was passed in 1894 defining

in the clearest manner the mutual obligations of the users of water, and providing for the imposition of penalties on those who contravened its regulations. The law is a judicial one only, the administration of water is left entirely to Government. This may appear a drastic measure, but, in the management of a large irrigation system, liable to shortage of water, is very necessary, in order that the spirit, as well as the letter, of fair distribution to all may be carried out. All disputes between users of water are, however, decided by a sort of moving water court, composed of the Governor of the Province, who is an Egyptian, two prominent men of the district, nominated by both contending parties, and the Irrigation Officer. This last advises on issues of fact for the information of the "water court," which then gives its decision in accordance with the terms of the law.

Now, Egypt and South Africa have not a single point in common, either in their physical features or in the characteristics of their inhabitants.

In Egypt, irrigation of a primitive kind, but extensive in amount, has been practised from the earliest times. In South Africa, or, at any rate, in the Transvaal, irrigation such as will enable the natural resources of the country to be fully utilised is not possible under the present water law. There is an oft-quoted proverb relative to the natural tendency of man to insist on purchasing his own experience; an expensive process. It is to be hoped that South Africa, with the mistakes of other countries to guide it, will not insist on taking the circuitous route to prosperity that they have done, but will display sufficient acuteness to take the obvious short cut to extensive irrigation which, if not absolutely necessary for, is, at least, a powerful aid to agricultural development that a good water law affords. In spite of the dissimilarity between the two countries, and, assuming that extensive irrigation in South Africa may be permitted, some useful lessons can be drawn from Egypt that are applicable to this country.

The first of these is that the study or construction of large schemes is not inconsistent with the execution of small ones. The investigation of the Nile as a whole, and the construction of large works on it in no way interfered with numerous small works being constructed to distribute water fairly to every cultivator, some of whom owned not more than half an acre. Similarly in South Africa the construction of large works need not, if properly carried out, interfere with small ones for individual farmers.

The second is that engineering details should not be interfered with except by engineers. Had Mehemet Ali and the rulers that succeeded him allowed the French engineers to build the Barrage in their own way, instead of insisting on an original and somewhat peculiar method of treating foundations, that structure would have been capable of doing its work in 1861, if not before. Egypt, consequently, would have reaped the benefit of it at least twenty years before it did. Instead of this, the work stood, a monument of

amateur interference, until 1890, and is still a source of constant anxiety and expense. Few who have not seen it can thoroughly realise the destructive power of water, and if disasters are to be avoided in this country, irrigation works in it must be made secure and sound, even if the precautions, that appear to the uninitiated unnecessary, are costly. The third is the control by the State of large streams. Under the old regime in Egypt, water was not thoroughly used, and all sorts of canals were dug, that, while benefiting the land of, probably, one rich owner, ruined, or tended to ruin, the land of his poorer neighbours by infiltration.

Under a clear law which, whether drastic or not, at any rate metes out equal treatment to all, regardless of influence or social position, the people are content, and full use is made of the water.

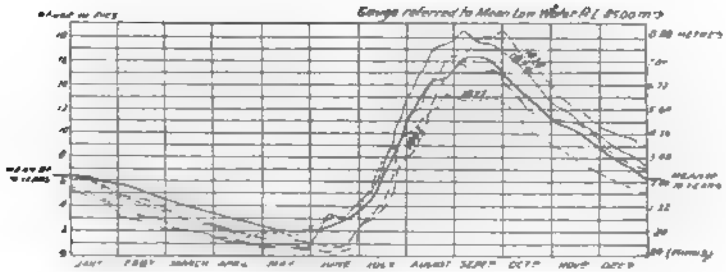
Under the present law in South Africa, the water is incapable of being fully utilised for irrigation, and will continue to be so unless controlled by the State, or by some other body that can be trusted to administer it in a perfectly unbiassed and impartial manner, and with a view to its thorough utilisation.

The fourth is the necessity for regarding irrigation development on broad lines, and not as a petty matter of politics. Egypt in this respect has been fortunate. Its Government is autocratic, and it has been possible there to carry out the large development of the country without the constant and vexatious interference in matters of general policy that are almost sure to arise under a popular and party form of Government.

Had the construction of the Barrage in 1833, or its repair in 1833, been decided on by popular vote, it is morally certain that the inhabitants of a country already burdened with debt would have refused to incur further liabilities. Egypt then would have continued to produce staple crops of beans and barley instead of the rich one it now exports. It is also almost certain that a plebescite would have vetoed the construction of the dam at Assouan, or other large works designed to improve, in a way they did not understand, the summer supply of water.

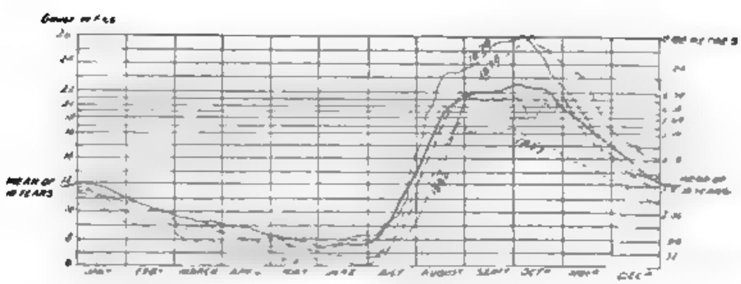
South Africa has a more intelligent population than Egypt, and any irrigation schemes in it will be much smaller and more obvious than those in that country. Still, there is a little danger that irrigation schemes may be blocked for want of funds, due to the desire of particular districts that the money should be distributed among them for farm improvements or very small dams for stock. Such improvements are not inconsistent with expenditure on larger works, but unless the subject is looked at from the standpoint of general development, it may happen that sums subscribed by the general taxpayer may be used solely for the benefit of particular individuals without materially increasing the general wealth of the country, and that the available water will not be made thorough use of, which would practically entail the loss of a national asset.

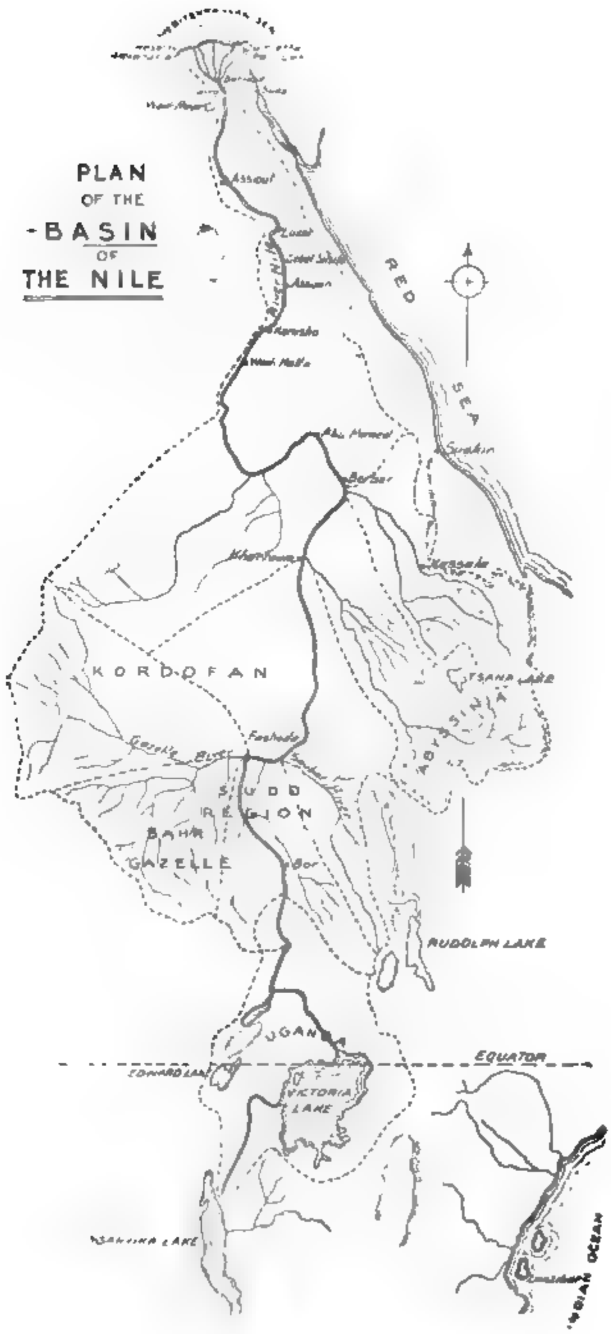
ASSUAN GAUGE DIAGRAM
1874. 1877. 1878. 1883.



1874 1878 Highest Floods on record Inundations | *1874 Maximum early in September not so bad*
1877 Lowest Flood Famine in Upper Egypt | *for the country as 1878 with max^m in October*

CAIRO GAUGE DIAGRAM.
1874. 1877. 1878. 1882.




PLAN
OF THE
BASIN
OF
THE NILE
RED SEA
KORDOFAN
SUDD REGION
BAHR GAZELLE
ABYSSINIA
TSANA LAKE
RUDOLPH LAKE
UGANDA
EQUATOR
VICTORIA LAKE
INDIAN OCEAN

46—SANITARY SCIENCE.

By James S. Dunn, A.R.S.I., A.R.I.P.H.

A general discourse on Sanitary Science, even at a Congress like this, would, I fear, be of little avail, for under the title are included the questions of providing communities and individuals with Pure Air, Pure Water, Pure Food; the consideration of Climate and Soils; the healthy construction of Habitations, Schools, Workplaces, Prisons, Hospitals, Barracks, and other buildings, and the Ventilation and Heating of the same; Infectious and Contagious Diseases and Disinfection; Offensive Trades; the Removal and Disposal of Sewage, Refuse and all Waste Matters, and the Disposal of our Dead. These sub-headings are in most cases vast subjects in themselves, and impossible of adequate treatment in a short paper; that, however, with which I intend making an attempt to deal, and that only briefly, is the question of the removal and disposal of Waste Matters.

Having accepted the duty, and decided upon which sub-division of the subject I will write, it becomes my deep concern to consider whether I cannot place before you for your consideration, something new, something important, something which affects the welfare of communities in general, or something which affects this country in particular.

Man in his primitive state had little occasion to worry about Sanitary Science. He alone could not contaminate the air he breathed nor the water he drank, and it does not appear likely that he would attempt to defraud himself by adulterating the food he prepared for his own consumption. He was his own Doctor, his own Architect, his own Local Authority and Sanitary Inspector. With the increase of population, and the formation of small and large communities, an unnatural state of affairs was brought about; unknown diseases appeared, and man in his ignorance could not at first tell what caused them, nor how to cure or prevent them. Experience and knowledge, however, have throughout the course of ages taught so much, that it is now possible for thousands of persons to dwell in health and comfort on an area where only tens could have lived in safety in past ages. Complicated questions have been gradually solved by wonderful feats of engineering. Water and food are conveyed to huge communities from long distances, and waste matters are removed therefrom and disposed of in various ingenious ways. These are but a small portion of Sanitary Science.

It has been written that outside the range of party politics there is no subject on which so much envy, hatred, malice and all uncharitableness prevail as on the treatment of sewage, and this is not difficult to believe when it is discovered that during the forty years ending 1886, four hundred and fifty-four patents were taken out dealing with sewage. What has been the number since I am not in a position to state. To the student of the subject there is considerable interest in tracing the improvements and development in the collection, removal and disposal of sewage during the past fifty

years, and, more particularly, perhaps, in the actual Sanitary Appliances used in and about buildings in connection with what is known as the water carriage system. It is not of this system, however, that I propose writing now, but rather the Dry Earth or Pail System which is so prevalent in this country, and with which so little headway seems to be made, it being recognised more or less as a makeshift system, incapable of improvement, and only tolerated until it can be superseded by a sewerage scheme. But for many years to come, in the smaller inland towns and villages especially, it appears very doubtful, owing to the high price of water, its scarcity, or other local drawbacks, whether what is recognised by many as being the ideal method of sewage removal, will be attained.

It is almost with fear and trembling that I approach the real subject of my paper, lest I be charged with advocating a system which it may be considered should be relegated to the past. Let it be remembered, however, that it is the improvement of a system that cannot be avoided, that I am urging, and I am doing so having a full knowledge of the many advantages of the water carriage system, and also its disadvantages. I feel that no useful purpose would be served by a long harangue on this latter method. I have no elaborate drawings for you, no bewildering statistics, and no comparisons of costs.

My paper, which has been prepared hurriedly at the last moment under the stress of anxious official duties, shall be so simple in character, that you may deem it scarcely of sufficient merit to be included amongst others that will be delivered before you; but the subject of Sanitary Science was given me, and I selected what I considered to be the most important branch of that Science affecting many inland communities to-day. Should any good result from my directing your thoughts in a certain direction I shall be more than satisfied.

The Pail System for the removal of Night Soil is carried out in the various towns of this country according to the dictates of the Municipalities concerned. In some cases by contract, in others departmentally. At some places large receptacles are in use, being removed once a week, or a fortnight might be allowed to elapse.

At other places quite small pails have been adopted, the removals being effected every 24 or 48 hours. In one important town the work of removal is, I believe, carried out in broad daylight; it is usual, however, to select the dead of night. Sometimes the receptacles are hermetically covered and placed in closed vans, or the contents are discharged into tanks and the empty buckets stacked in a box-like arrangement in the fore-part of the vehicle, as in Kimberley. Take any one of these methods, and I think there is no doubt but that disadvantages predominate. Offensiveness or inconvenience is caused at one stage or another, either through the receptacles being allowed to remain too long on the premises, or during the process of removals, and it is small wonder that the man in the street clamours for reforms.

To my mind, the first reform should be the abolition of the contract system, and all Municipalities should take upon themselves the entire burden of performing this important work, which so closely affects the public health. If a profit can be made from it, that profit should go to the people; if a loss is the result, the people should bear the loss and not a private contractor. If a private contractor can make the work pay where the Municipalities fail, surely there must be something wrong with the Municipal machinery requiring adjustment. There is a certain amount of expert knowledge to be gained from the actual performance of the work, and it appears to me far preferable in the interests of the community that the Municipal authorities should be in full possession of all facts rather than a contractor. Improvements can be far better effected from time to time as occasion may demand under departmental working, and in time of epidemics there is no doubt regarding who should bear the brunt.

As regards other needed reforms, I have already mentioned that offensiveness can be caused either through receptacles being allowed to remain too long on premises, or during the process of removals. In what manner, therefore, can improvements be effected in order that annoyances and discomfort are reduced to a minimum?

Dr. George Ried states, the great principle to keep in mind is the checking of decomposition. . . . Warmth and moisture are the great agents that encourage putrefaction. . . . Dry fæcal matter, comparatively speaking, does not decompose rapidly, but, when mixed with water, or, what is worse, Urine, the change takes place almost immediately.

Many and varied efforts have been made to introduce a suitable closet and system of removal which would meet with the above requirement; Moule's Earth Closet is probably too well known to require description here. Others might be mentioned, but as they do not comply with the principle laid down above, I do not think it necessary to deal with them in this paper.

It is very striking indeed what an improved state of affairs can be brought about by rigidly excluding all liquid, including Urine, from the solid excrement; and, from the moment this is done, it is a comparatively simple matter to deal separately with the Fæces, and Urine, the former being treated as a solid, and the latter as a liquid. It is repulsive, expensive, and unsatisfactory in every way, attempting to dispose of a half-solid, half-liquid mass in such matters.

I feel convinced that not nearly sufficient earnest attention has been given to this subject. I find that in 1857 F. H. Maberley patented a mechanical arrangement for separating the solid from the liquid portions of sewage, but I know nothing further about his contrivance; probably this was for dealing with a whole town's sewage after having been knocked about through miles of pipes. I also feel that, had the water-carriage system not made the rapid progress, which has been the case during the last sixty years, the

conservancy system would have probably attained a far higher state of perfection.

The late Dr. George Vivian Poore, M.D., Fellow of the Sanitary Institute, was an eminent practical Sanitarian, and deeply considered the question of the satisfactory disposal of all waste matters. He was entirely opposed to sewerage schemes, but his theories were propounded somewhat late in the day. Writing in England in 1893 he states: "Sanitation is a purely agricultural and biological question. It is not an engineering question, and it is not a chemical question, and the more of engineering and chemistry we apply to sanitation the more difficult is the purifying agriculture. This, at least, has been the practical result in this country." There is no doubt whatever, he also states, that whenever excrement is mixed with water we are in danger of Typhoid. Again, if excremental matters be excluded from the house drains, the total volume of sewage to be dealt with would be diminished by at least one-fifth, and this surely is a great gain. We should deprive the sewage of just those ingredients which are most troublesome to the sewage farmer by clogging the pores of the ground, and we should leave the sewage very thin and admirably suited to downward filtration. It seems to be an acknowledged fact that, for the application of sewage to land, the more watery it is, and the more completely solid matters are strained out of it, the simpler and more satisfactory the processes become.

Acting on the principles laid down by Dr. Poore, I advised the Kimberley Borough Council about three years ago (and I should here thank His Worship the Mayor for permission to refer to any matters connected with the Borough) to adopt a new system of Latrines at our Native Location, the details for which I supplied.

Prior to the outbreak of Plague in the country, Latrines were non-existent at the Location. At that time, however, a system of Trench Latrines was adopted. This system is disgusting in the extreme, and, in my opinion, more dangerous than the former primitive manner referred to. The problem had to be solved, but a pail service would have cost about £150 per month, and was out of the question on account of the prohibitive cost.

Two Latrines were erected as a trial, being so constructed as to immediately separate the urine from the Fæces. No pails are used; the solids remain on a slightly sloping granolithic floor, and are removed daily and buried, in a dry state, in the top-layers of the soil, in close proximity to the erection. The urine is conveyed from the sloping floor to a granolithic trough, filled with soft wood sawdust, which from time to time is removed and buried, in like manner, when fresh sawdust is supplied. The trial of these Latrines was so satisfactory, that the Council has since decided to erect a sufficient number for the entire Location of about 8000 inhabitants. The cost for cleaning the whole lot has never exceeded 30/- a week; they have never been offensive; by proper daily attention it is an impossibility. Thus by simply separating the liquid

from the solid a monthly saving of about £140 for maintenance has been effected.

Since leaving Kimberley for Johannesburg, Dr. Turner, the late Medical Officer of Health, has applied to me for full particulars, with a view to erecting similar ones in his new sphere of action, and Dr. Ried, the present M.O.H. for Kimberley, has expressed his entire approval of the Latrines and the manner in which they are worked.

During the present year I have been entrusted with the working of the Sanitary Service of this town, and as soon as possible preparations were made, experimental at first, at the Municipal Sanitary Site, for separating the liquids from the solids. Formerly the tank wagons discharged their contents into trenches, the overflow water from which was conveyed to large pits. My new process, which is still in the embryo stage, will separate the matters as they leave the wagons, the liquid running into a channel, from which it will be pumped and distributed over the ploughed surface of the ground, and the solids will be stacked in layers with red ground in galvanised wire-netting bins for future use, I hope, for fertilising purposes. As a result I shall look for a saving in working expenses, a minimum amount of offensiveness to the senses, and eventually extensive cultivation, though I anticipate difficulty with the liquid unless dilution be possible.

I have endeavoured to emphasise the necessity of keeping free, or freeing, solid excrement from liquid of any description; this really is the whole purport of my paper, and I trust that I have not wearied you in the attempt, but I consider the matter of high importance, and worthy of further following up. There is still something more to which your attention should be drawn in connection with the subject. A dry earth closet, known as O'Brien's, and which hails from Australia, I believe, is well known in the Cape Peninsula, and through my suggestion has been adopted in the Kimberley Town Hall, and is also being installed at the Public Latrine on our Market Square. It may not be generally known, however, that this closet separates the liquid from the solid excrement, by means of a perforated pail, the urine being received in a receptacle underneath. The system is admirable where it can receive the little due attention it requires, and I have nothing but praise for it. I am not in a position, however, to recommend its universal adoption as yet, owing to the misuse to which it may be subjected at some hands. But there are many points in its favour. It is the least offensive earth closet I have experienced; the pail being removed from the front, there is no draughty flap at the back to worry one; and certainly if this system could be universally adopted, there would be no unpleasant odours floating about our streets during the process of removals; with this system the removals could, in my opinion, be safely carried on during the day.

I have now given three instances, and all are in connection with this Borough, of satisfactory results following the principles laid

down in this paper. At our Native Location, on economical, sanitary, or efficiency grounds, I am certain that the present system in vogue is superior to any conservancy system yet devised. At our Municipal Sanitary Site, the same advantages are being proved, but I must admit that I should have liked my work there to have had a longer test before writing about it. As regards O'Brien's Closet, I pointed out that it is the least offensive earth closet that I have met, and I believe that if universally adopted this method could be worked cheaper than the ordinary pail system, but I have stated that I cannot yet recommend its general use.

You will agree, I think, from the details I have here given you, that the Pails System, as carried out in this country, is capable of very great improvement, and that it is only right for the comfort and well-being of all concerned that where it is intended to continue such a system every effort should be made to conduct it upon the best possible lines. I have carefully refrained from arbitrary details; they can be varied and still be correct. It is the principle which I feel is not sufficiently well known, upon which all stress should be laid. It must ever be remembered that to mix liquid of any description with solid excrement is dangerous, disgusting, and complicating, and has caused deaths incalculable, both through cesspools and sewers. It is, I think, entirely unnecessary to discourse further on the method herein alluded to, for I am certain that if any one of you will but experiment in a proper manner upon the lines laid down, you will be astonished with the success that will be achieved.

So far my paper has only dealt with the disposal of solid excrement, and may consequently be considered incomplete without some reference to the disposal of urine and slop water. It is not my intention, however, to deal with these matters at length now. Suffice it to say that at my Latrines in our Native Location the urine is most satisfactorily dealt with in the soft wood sawdust, being ultimately buried as a solid manure. In the O'Brien Closet, too, it is received into a receptacle under the perforated pail into a mixture supplied by the patentee, and causes no offence. Several successful filtering urinals have been devised, and some are even in use in this country and Australia, and in the Northern Countries of Europe, where it has been found impossible to adopt the water-carriage system, and the question of improving their other methods has been directly forced home to the people.

As regards the removal and disposal of slop-water, if other means are found impracticable, a partial or complete system of slop sewers could be adopted, which could be far less intricate, far less expensive, than sewers to take solid sewage, and could also be made self-cleansing without requiring clean water to flush them. The argument that if sewers be constructed they may be made to take everything, is wrong, for then, as I have tried to point out throughout this paper, our troubles would begin, and it is difficult to say when or where they would end. I do not wish it to be

thought that I am entirely opposed to sewage sewers, for towns are allowed to grow to such lengths, and carry such enormous populations on small areas that sewers are undoubtedly a very quick and easy manner of removing foul matters. But because it has been found necessary, no other satisfactory means having been discovered, to introduce sewage sewers into our larger towns, it does not follow that every town and village should be so provided, and therefore when other methods are in vogue at these places, let them be as decent as possible, and improved upon at every opportunity.

There were other questions connected with Sanitary Science to which at first I intended referring; I think, however, that I have chosen the most urgent portion of my subject, and that it has been amply sufficient for the scope of a short paper. Before finally concluding, a few words with reference to the work of the Sanitary Inspector in this country may not be out of place. Year after year Blue Books are published dealing with the Public Health. Insanitary conditions are continually being pointed out. Suggestions have been made that Sanitary Inspectors should be appointed under Divisional Councils to supervise the work of sanitation in the various villages within their area, but I have not heard of a single such appointment being made. Qualified Inspectors have been brought into the country by Municipalities from time to time, but, to my knowledge, several have drifted into other professions and others may follow their example. This surely is a pity, and a retrograde rather than a progressive movement. It is important, I think, that Municipal Officials should be more in touch with one another for the interchange of ideas. Sanitary progress has been very slow, and will continue so, so long as the smaller towns and villages fail to appoint qualified men and try to improve matters by simply writing to another town whose system might be good or might be bad, but totally unsuited to those seeking information, though no one is in a position to point this out.

It is with appreciation that I acknowledge the honour of having been asked to write this paper, and the duty has been a pleasure to me. I trust that my views have been clearly expressed, and if it is considered that they have been directed in the right direction that good will result. Personally, I shall look forward with interest to perusing papers on this or other branches of this subject in connection with future Congresses of the South African Association for the Advancement of Science.

47—ON THE CONSTRUCTION OF SCHOOL BUILDINGS.

By G. Bernfeld.

(Title only printed.)

48—FARM IRRIGATION IN THE TRANSVAAL.

By C. D. H. Braine, Assoc.M.Inst.C.E.

In January, 1905, the Governor of the Transvaal and Orange River Colony appointed a Commission, known as the Inter-Colonial Irrigation Commission, to enquire into and report upon many important questions referring to irrigation in the two colonies. The Commission consists of :—

The Hon. Mr. Justice Wessels.
Mr. W. L. Strange, M.Inst.C.E.
Mr. J. Rissik.
Mr. J. A. Neser.
Mr. E. Rooth.
Mr. G. D. Adamson.
Mr. E. R. Grobler.
Mr. D. C. H. Braine, Assoc.M.Inst.C.E., Secretary.

Part of my duty, as Secretary of the Commission, was to hold meetings in various parts of the Transvaal, so as to explain to farmers, and others, the work being done by the Commissioners, and to discuss with them the various suggestions under consideration. The total number of meetings held amounted to thirty-seven, and in going from place to place I have travelled over the greater part of the Transvaal. During the tour I took every opportunity of visiting the irrigated farms along the route, and I found farm irrigation in a very primitive condition. One or two farms stand out as brilliant examples of what can be done; but in most cases the work is very unsatisfactory and shows great lack of knowledge and care, water being often badly and wastefully used. Proper irrigation is the result of scientific as well as practical knowledge, and the most successful men are those who irrigate with due regard to scientific principles. These principles are not generally understood by our farmers, and I believe no experiments on the duty, and use, of water have ever been made in South Africa until last year. It is greatly to the credit of the Transvaal Agricultural and Irrigation Departments that such experiments are now being carried out at Potchefstroom; but they have not been instituted long enough to give decisive results. Many experiments of the sort have, however, been made in the United States of America, and, as the climatic conditions in the Western States are so similar to those in South Africa, the important results obtained should be invaluable to irrigators in this colony, and form a useful guide to our own experiments. The bulletins and other publications on the subject are not known to the average farmer, and it should be part of the duty of every Irrigation Engineer to keep in touch with the work being done in other countries, and impart the knowledge to our agriculturalists. There is so much to be learnt on the subject, and the results are of such great economic value, that it would be in the interests of agriculture if Government experiment irrigation stations were started in various parts of the country.

To give an idea of ordinary farm irrigation, I will describe the conditions existing on a farm that I inspected. The system employed was undoubtedly injurious to the crops. The orange trees were growing in the furrows, and were naturally in an unhealthy condition. The young shoots were dying off, and the leaves turning yellow, altogether showing signs of improper irrigation. The water should have been kept well away from the base of the trees, so as to induce the roots to spread. It is a rule amongst advanced irrigators never to irrigate within the area covered by the shade of the tree at noon; but the irrigation of fruit trees on that farm is limited to this area. Consequently, all the roots are confined to a restricted space close to the trunk of the tree, and, should no irrigation be possible during a drought, many of the trees would undoubtedly perish. Then, again, it is the custom on that farm to irrigate twice a week, using comparatively small quantities of water: for orchard irrigation this is a fundamental mistake. The small crop of oranges on the mature trees was ample proof that the system of cultivation was radically wrong. It is also a great mistake to plant fruit trees in the water-logged soil near the furrows. I have seen several instances of diseased trees caused by this, and one of the leading farmers of the Rustenburg district told me he had noticed the same thing. A friend of mine in Kimberley once expressed his surprise that, although he irrigated his trees every day, he never got any fruit. That was a natural result of over-irrigation, and if scientific irrigation were better understood there would be fewer disappointments.

Now I will give an example of better methods. It is in the Barberton district, and the farmer in this case has one of the healthiest looking orange orchards that I have seen in the Transvaal. He grows nothing but trees in his orchard, and there are neither grass nor weeds. The surface-soil is broken into a loose tilth which prevents the sub-soil drying up, and when he irrigates, the water is allowed to soak into the ground between the trees. This he only does twice a year during the winter, and after irrigating the surface is well cultivated. There were no symptoms of root-rot and no leaves turning yellow. The farmer knew that the roots extended over twenty-five feet from the tree, and it was those roots he wanted to water. I saw another notable instance on a farm in the Rustenburg district where the water supply had practically ceased; but there again the surface was covered with a fine tilth, and under the branches, where the plough and harrow could not be used, the soil was broken up with a fork. The correct practice is to apply heavy irrigations at as long intervals as possible, depending on the nature of the soil and the kind of tree, and the distance from the trunk at which the water should be applied varies with the size of the tree. This perennial variation induces the roots to spread themselves out towards the moistened soil, producing a larger area from which the tender roots can draw nourishment and moisture. If copious irrigations are used, the trees become deep-rooted and will safely withstand any ordinary drought.

I have seen many farms where the field furrows have been laid out on far too steep a gradient—so steep that an appreciable quantity of soil is being washed away at each irrigation. This, of course, is quite wrong, for it not only carries away some of the best soil, but also cuts up the fields very badly. Then, too, the beds, or acres (as they are sometimes called by the Dutch farmers), are not properly prepared. It is not enough to plough them and turn in the water: they should be carefully levelled, so that the water will spread gradually over the surface. Where the furrows and beds have a gentle slope the water has time to sink into the soil, which it does not do to the same extent when rushing over the ground. One has only to examine the lower edge of the fields to see the waste of water and land that is constantly occurring.

One of the most important crops in the Transvaal is tobacco, and there again, in my opinion, the system practised is harmful. All the plants are grown in the furrows, and in the early stages the young plants are often entirely submerged during the process of irrigation, and the leaves covered with a deposit of silt, which prevents them from performing their natural functions. Little or no attempt at cultivation or inter-tillage is practised, and naturally the ground becomes hard and baked, thus supplying the conditions favourable to evaporation. I have seen young tobacco seedlings, as tender as water-cress, struggling through the caked surface of a dry furrow. Then they irrigate to soften the ground, and water is applied too frequently. With proper deep irrigation it would be quite unnecessary to irrigate every two or three days, as is the usual practice at present. The young plants undoubtedly require an abundant supply of moisture; but the larger plants, if well rooted, as they would be with deep irrigation, ought seldom to require watering more than once in ten or fourteen days. It is a common thing to see the lower leaves attacked by a white mould. On some farms it amounts to from 20 per cent. to 30 per cent. of the leaves, and those that are badly affected can only be used for Kaffir tobacco. One of the best known growers in this Colony agrees with me that the mould is largely due to the system of irrigation practised. He also agrees with me that the tobacco plants should be grown between, and not in, the furrows; but he was afraid it would take more water and more work. I pointed out that by this system fewer irrigations would be necessary, and, consequently, less work leading water. I admit it would require more care, but the tobacco planter would be amply repaid by a better crop of leaves. It is the opinion of experts that a lighter and thinner leaf would be grown if the tobacco plants were placed together more closely in the rows; but this would cause more shade, and some growers are afraid there would be an increase of the white mould. This would probably be avoided by a better system of irrigation, but such questions will only be definitely settled by expert observation on experiment irrigation farms.

The amount of tobacco of all sorts imported into the Transvaal during 1904 was £202,575, and in 1905 it increased to

£243,702. Now, if this valuable local trade is ever to be retained in our own hands, the tobacco growers must produce larger quantities of improved leaves of uniform quality. It is quality, and not weight, that is going to pay in the future.

Many people in South Africa appear to think that irrigation consists entirely of the works necessary for storing, or diverting, water and delivering it to the farmers; but while I fully realise the importance of the work that has to be done by Irrigation Engineers, I am also aware that real development does not rest solely with them. The economical and scientfic use of the water by farmers is a very important factor, and that is the point to which I would like to give special emphasis. The methods employed to-day are little better than those employed by the early settlers. It has been the same in the United States, but the go-ahead people there are alive to the importance of the proper use of water, and the question is being investigated by experts. It has been found that the area of land that could be irrigated by the rational use of water might be doubled or trebled, and it is easy to see what an advantage that would be to this country. It would mean that the cost per acre for water would be reduced to one-half or one-third. This saving of water is obtained by only using the amount required to get the best results. Different crops require different treatment, and improper irrigation is injurious to any crop; for instance, oats require more water than any other grain, cotton needs very little, too much water spoils tobacco, turnips, parsnips and carrots should never be flooded, and flooding lucerne during the first six months of its life is pretty certain to check the growth.

Much valuable information was given by Dr. J. Widstoe in a paper read before the Twelfth National Irrigation Congress in the United States of America. He said that on a typical western soil, 5 inches of water produced 33 bushels of wheat per acre; 10 inches of water produced 40 bushels. Adding more than 20 inches of water to the field did not appreciably increase the yield of grain. In the case of the wheat plant, then, the increase of the amount of water up to about 15 inches increases the yield of grain, but a further application tends to diminish the yield. When it is considered that the depth of water applied to the wheat, over a very large area of irrigated country, amounts to 30 or more inches annually, it will be understood what a loss in wheat alone occurs year after year through the misuse of water.

With oats the variation is somewhat similar. Five inches of water in one set of experiments yielded about 58 bushels of oats per acre; 10 inches yielded about the same amount, though the increased quantity of water increased the weight of the straw. With 15 inches 70 bushels were obtained: with 20 inches 86 bushels; and with 30 inches 82 bushels. Covering the land with more than 30 inches of water diminished the yield of oats decidedly. About 20 inches is therefore the best amount of water for oats; yet throughout the irrigated West 30 inches or more are generally used in the

production of oats—and thus again the wasteful use of water is emphasised.

It is generally true with all the ordinary crops grown in the Western States, that increasing the amount of water increases the yield up to a certain point, after which an increase in the water causes a decrease in the yield. Not all the crops are alike in this respect, however. Some crops, because of their nature—leaf surface, root system, etc.—find 10 inches of water about right for the season's growth. Other plants, because of their different natures, find 15 inches or 20, or 25 to 30 inches the best. Now, the farmer in an irrigated district should know the water requirements of the different plants that he grows as thoroughly as he knows the soil of his farm, his water right, or any other matters upon which his success as a farmer depends. Not all plants decrease in yield after a certain amount of water has been applied. Potatoes appear to be a crop, the yield of which increases continually if water is applied, up to the limit of the practical application of water. To illustrate:—in one set of experiments, 7½ inches of water produced 160 bushels of potatoes; 15 inches 233 bushels; 30 inches 274 bushels; and 71 inches 315 bushels. This illustrates the necessity for the farmer to thoroughly understand the nature of the plants with which he is dealing.

It may be noted, in reviewing the yields of wheat, oats, and potatoes just considered, that the value of the first few inches of water applied is much greater than that of the later applications. For instance:—5 inches of water produced about 33 bushels of wheat, or about 6.6 bushels per inch; 15 inches of water produced about 40 bushels of wheat, or about 3.2 bushels per inch of water; while 20 inches of water also produced 40 bushels of wheat, or only two bushels per inch. The value of the first 3 inches of water applied to wheat, therefore, is more that three times as much as the value of the last 5 inches, in a total depth of 20 inches. Similar results may be observed in the case of oats. Five inches of water produced 58 bushels, or 12 bushels per inch; while 20 inches of water produced 86 bushels of oats, which is less than 5 bushels per inch of water. The difference is certainly very striking. Even in the case of potatoes, the yield of which increased steadily with the increase of irrigation water, the same fact holds. Seven and one-half inches of water produced 160 bushels, or about 22 bushels per inch; while 30 inches of water produced 274 bushels, which is only about nine bushels per inch. Corn, alfalfa (lucerne), the various grasses, sugar beets, vegetables and all other crops show similar results; namely, that the value of water is highest when it is used sparingly and carefully; that the value of water is lowest when it is applied liberally and carelessly. With this generalisation in mind, note how these results may be viewed in their relation to the increase of the irrigated area.

According to the investigations of the Department of Agriculture, under the direction of Dr. Mead and his associates, 30

inches of water, or more, are used in the majority of places in the irrigated districts for the production of crops. Let us apply the varying value of water as just explained, to the economical, or rational, use of water. If the 30 acre-inches be spread over 6 acres of wheat, so that the whole area of 6 acres will be covered with water to a depth of 5 inches, each acre will yield 32½ bushels of grain, or a total of 195 bushels. If the same amount of water be spread over 4 acres, that is, to a depth of 7½ inches, the total yield of grain will be 165 bushels. Spread over 3 acres, to a depth of 10 inches, the same amount of water will yield 118 bushels. Spread over 2 acres, to a depth of 15 inches, the total yield will be 95 bushels, and spread over 1 acre, to a depth of 30 inches, the yield will be 42 bushels. It may thus be seen that, in the case of wheat the total amount of grain produced by 30 acre-inches of water may be increased from 42 bushels to 195 bushels by spreading the water over more or less ground. Certainly the nearly five-fold increase of grain thus made possible, will more than pay the farmer for the labour of handling six acres of land instead of one; and of higher importance is the fact that, by using the water rationally, the irrigated wheat area may be profitably increased four or five times without building another reservoir or canal.

These figures show how enormously a farmer can increase the area of land irrigated by a given quantity of water if he understands its scientific use. It is a subject worth studying, for on it depends to a large extent the agricultural prosperity of the country. Farm irrigation in South Africa has not received the attention it deserves, and I am looking forward to the time when the Transvaal will have Government experiment irrigation stations in various districts, under the superintendence of expert engineers and agriculturalists. They will be attended with the most valuable results.

49—POWER GENERATION AND DISTRIBUTION.

By R. A. Dawbarn, M.I.C.E., M.I.E.E.

Just 600 years ago the British Parliament successfully petitioned the King to prohibit the use of coal in London, from which time its consumption gradually increased, but it is only within the lives of living men that the great demand for it has arisen for the generation of mechanical power, with which we are for the moment more directly concerned.

It is almost startling to recall the fact that only 70 years have elapsed since mail coaching was at its height—a zenith represented by 54 coaches throughout England, together unable to carry as many passengers as a single railway train to-day.

But it is perhaps still more remarkable that 20 years from the height of its prosperity sufficed to entirely supersede the mail coach * and to establish the *age of mechanical power*.

Closely following the spread of railways came that rapid development of trade, demanding the use of power for almost every manufacturing industry, and with this demand a corresponding increase in the consumption of coal, until, at the present time, its output in England is fully 7 tons per annum per head of population.

But the consumption of coal in the Transvaal—chiefly for the generation of power—already exceeds 10 tons per head of white population, and anything which affects economy of fuel cannot fail to be of importance to South Africa.

Although the demands for power have been increasing with marvellous rapidity for half a century, singularly little advance has been made since the days of Watt in reducing the consumption of coal per unit of mechanical energy obtained from it, in spite of the realization of the fact that manufacturing countries must inevitably lose some all-important industries so soon as the cost of coal is seriously increased by the necessity for obtaining it from greater depths.

It is both difficult and expensive to provide means for accurately recording the average power consumed in factories in which many power-using tools are intermittently employed, except where electric motors are in use when accurate records of the energy absorbed—however intermittent the load—can be obtained automatically, by the use of meters. It is therefore only since the establishment of electric distribution of energy that accurate costs of generating and distributing power have been systematically recorded.

On setting to work the earlier electric power stations, it was a surprise to most engineers to find how large the consumption of fuel was per unit delivered to the consumer. Consumptions of coal as high as 15 lbs. and more per unit sold, with non-condensing engines, were not uncommon, whilst 12 lbs. per unit sold was frequently experienced with condensing engines.

Note.—The first mail coach ran in 1784. The height of coaching was reached in 1838. The last mail coach from London ceased running in 1856.

Even to-day there are few electric power stations in England consuming less than 6 lbs. of coal per unit sold. Of the 26 electric supply undertakings in the London Metropolitan area, supplying over 150,000,000 units a year, the average cost of coal in 1905 exceeded 0.5d. per unit sold. Assuming the average cost of coal to be 15/- per ton, this corresponds to an average consumption of 6¼ lbs. per unit sold. The average thermal value of the coal probably exceeds 13,500 B.Th.U. per lb., on which basis 84,375 B.Th.U. are thus expended per electrical unit sold in London, whereas an electrical unit corresponds to 3,438 B.Th.U., consequently the overall thermal efficiency, that is to say, the proportion of the latent heat energy contained in the coal, which is recovered in the form of electric energy at consumers' premises throughout London, is practically 4 per cent.

By employing a small number of correspondingly larger engines of the most economical type, this efficiency ought, in the light of our present knowledge, to be greatly improved, but it is doubtful whether, with the most economical steam plant, and with the highest load factor obtainable under practical conditions, it is possible at the present time to generate and distribute electric energy 24 hours per day over a large area—involving extra high pressure mains and the consequent transforming losses—with a higher overall thermal efficiency than 8 per cent.

The following figures show approximately the distribution of losses, giving this result :—

		Resulting efficiency.
Boiler efficiency	70%	12·88%
Engine and dynamo 16 lbs. steam per unit ...	18·4%	
Increased steam consumption due to engines being at times uneconomically loaded ...	10%	11·59%
Losses by radiation from steam pipes, blowing off boilers, &c.	10%	10·43%
Power absorbed by station auxiliaries ...	5%	9·91%
Losses in electric distribution including transformers	20%	7·93%
Say		8%

In view of the last-mentioned loss, it may at first sight be difficult to realize that a power-user, developing his own power direct by modern engines, could under any circumstances be supplied from a distant steam-power station at a lower price than his own cost, with profit to the supplier, for the following reasons :—

(*a*) The Power Distributor must (generally speaking) generate his own power in similar manner, and can only obtain comparatively small advantage in the higher efficiency of larger generating units.

(*b*) The Power Distributor has to incur the additional losses of converting his mechanical power as given off by the engines, into electrical power. He has also to incur losses in transmission, and must cover the consumers' losses in reconversion of the electrical energy into mechanical energy.

(c) The Power Distributor must incur heavy capital outlay in dynamos and distributing mains, which the power-user, employing his own direct power plant, avoids.

The author's object is to show, firstly, why it is possible under certain conditions to supply fairly large power-users by electrical distribution from a distance with advantage to both supplier and supplied, and, secondly, to point in general terms to the limitations of electric Power Distribution.

The advantage of the Power Distributor over the ordinary power-user employing his own plant, may be briefly described under the following headings:—

(1) Large output.
(2) Low Diversity factor.
(3) Large Station load factor.
(4) Large Plant load factor.

1. LARGE OUTPUT.

It will be readily understood that as there are many charges which do not increase pro rata with the output—such, for instance, as management, attendance, and even stores and repairs to a lesser extent—the larger the service from one generating station (within limits) the lower will be the cost per unit generated. Larger generating units are, moreover, more economical in fuel consumption than smaller ones, and require less attendance in proportion to the output.

2. DIVERSITY FACTOR.

The diversity factor, however, plays a still more important part in establishing the advantage of electrical distribution of power. This may be best explained by a reference to a specific case:—

The Natal Government Railways have an electric generating station supplying power to their railway workshops at Durban. There are no less than 406 motors in use, arranged to drive a corresponding number of tools of various kinds. No motor is any larger than is necessary to drive the particular machine to which it is attached. The total power required to serve the whole of these motors at once on full load would be 2000 K.W., but it is found in practice that the maximum power required to supply their aggregate requirements never exceeds 500 K.W. This is due to the fact that without design a number of motors are always at rest for one cause or another, whilst other motors are for the time being required to give less than the maximum power which the tools they drive may at times demand.

It follows that in such a case the capacity of the generating station can be reduced to about 25 per cent. of that which would be required to work every motor at full load at one time. This percentage is called the diversity factor. Although in this case the motors are all in one factory, the principle would be the same if every motor represented a separate factory. It is clear that the aggregate capital expended by the many proprietors in order to

provide themselves with steam engines and boilers, or other sources of power, to the total capacity of the motors, would greatly exceed the capital to be spent on one generating station of only 25 per cent. of the total capacity comprising a small number of much larger and more economical generating units. The cost of working a large number of scattered small engines and boilers as compared with a few large ones in one building, would also be much greater.

3. STATION LOAD FACTOR.

In the case just cited, the working hours are the same for the whole factory; but when supplying a large number of consumers having very different businesses and different working hours, the duration of the average load will be extended. A generating plant, capable of developing 1000 H.P., would, of course, be capable of developing 24,000 H.P. hours per day, but if the aggregate load per day corresponds to only 8,000 H.P. hours, or one-third of the possible maximum—although the maximum power taken at some time during the day was 1000 H.P.—the load factor is said to be 33 per cent. In other words, the station load factor is a fraction of which the numerator is represented by the units generated in a given time, and the denominator by the product of the observed maximum load in Kilowatts, and the total number of hours in the given period—usually one year to cover the variations of the seasons.

The longer the machinery can be fully employed, the less, of course, will be the cost per unit generated, owing to the capital charges, management, and other costs, being reduced per unit, pro rata with the output.

4. PLANT LOAD FACTOR.

As a result of the diversity factor, it follows that the average load on a generating station, supplying a number of power-users, must be much nearer the maximum load than in the case of each individual motor, and it is well-known that a steam engine lightly loaded consumes considerably more steam per unit generated than at full load.

It is the practice in all generating stations to keep only so many of the generating units running as will cope with the total load for the time being. By this means it is frequently found possible, where the station load factor is, say, 25 per cent., to keep the plant load factor as high as 50 per cent., that is to say, the machinery in use is on an average half-loaded.

By increasing the number of generating units indefinitely, it would, of course, be theoretically possible to approximate closely to a 100 per cent. plant factor, but this would involve smaller and less economical units, greater capital outlay in plant and buildings, and greater attendance and repair charges.

In practice, about five running sets, and a sixth as a stand-by, is found to give economical results, though generating stations are

usually started with less generators to allow for increased demands without involving an undue number of generators later.

In estimating the cost of generating and distributing electric energy for any given case, one may calculate capital outlay, fuel and labour charges very closely, but the load factor and diversity factor, which have such an important influence on the working cost per unit and on the capital outlay respectively, can only be more or less closely approximated, according to the experience and judgment of the estimating engineer.

EFFECT OF LOAD FACTOR.

In England the load factor for lighting alone during 1905 was in one case as low as 5.75 per cent. There are 12 undertakings having load factors below 8 per cent., and 37 below 10 per cent. The average is about 15 per cent.

Stations which generate electric energy for both tramways and lighting have load factors usually between 20 per cent. and 25 per cent., but Salford has a load factor of 28.55 per cent., and South London 29.32 per cent. None reach 30 per cent.

A station supplying tramways only may have a load factor as high as 52 per cent. to 53 per cent., but the author is not aware of any public electric supply stations with a load factor as high as 60 per cent.

The effect of the load factor on the total cost of supply, including interest on capital, is shown by the following Table A. :—

TABLE A.

Shewing the effect of "load factor" on the cost of Electric energy supplied from a Public Supply Station.

Load factor %	Price in Pence per Electrical Unit.			Price per B.H.P. hour from consumers motor. II.
	Generating & Distribution costs. I.	Capital Charges II.	Lowest sale Price I. & II. III.	
5	2·25	2·63	4·88	4·05
10	1·58	1·31	2·89	2·40
15	1·19	0·88	2·07	1·72
20	0·92	0·65	1·57	1·30
25	0·76	0·52	1·28	1·06
30	0·67	0·44	1·11	0·92
40	0·61	0·33	0·94	0·79
50	0·57	0·25	0·82	0·68
60	0·53	0·21	0·74	0·61
70	0·51	0·19	0·70	0·58

The actual cost in a given case will, of course, vary according to the size of the station and the local conditions, which latter include the costs of coal and water, the cost of skilled and rough labour, also transport and import charges.

The Table shows costs applicable to a large power distribution scheme on the Rand. Whatever adjustments might be necessary for any given scheme, as between work's costs, distributing costs, and capital charges, it is not considered probable that a public supply will be given throughout this district at lower charges than are here shown.

A public supply system must include capital charges on a higher scale than would be required in the case of a private plant, in order to recover in later years the losses incurred during the time taken in building up the load from small beginnings to the scale that is necessary in order to reach the low working costs per unit sold, corresponding to the low tariff, which must be low from the outset. in order to justify consumers in adopting the public supply in preference to their own plant.

It has also to be borne in mind that public electric power supply undertakings are never completed. They are bound to keep ahead of the demand, which results in new capital always being spent, and, for the time being, unproductive.

In estimating the cost of supplying electric energy to a group of mines, it must not be overlooked that the "diversity factor" in such cases is somewhere near unity, as the maximum loads on the several mines practically occur simultaneously. The supplier cannot therefore in such a case secure the advantage, previously referred to, of being able to meet the consumer's requirements, with a lower capital outlay per Killowatt than the consumers would themselves incur in adopting their own independent power plant.

Where the load is practically constant—as, for example, a battery of stamp mills—there is no economical advantage in transmitting the power electrically. This would only be done when electric energy could be bought at a price which would show an advantage compared with the cost of applying the power direct from one large engine.

The following table (B) has been prepared in order to establish comparison between the assumed prices at which electrical energy may be purchased (Table A) and the cost of supplying power from the consumer's own plant, with or without electrical transformation.

The working costs are given for four sizes of engine—ranging from 125 Brake H.P. to 1000 B.H.P.—and for two load factors, namely 25 per cent. and 50 per cent.

The estimates are each based on the use of a single gas engine with gas producer plant, suitable for the use of bitumenous coal.

The cost of coal is assumed to be 12/6 per ton (200 lbs.) for the largest engine, rising to 14/- for the smallest engine, to allow for the smaller consumer buying less cheaply than the larger one.

The Public Supply Station is assumed to buy coal at 10/6 per ton.

TABLE B.

Estimated cost of Power on the Rand, developed by Gas Engines and Producer Gas on the Consumer's premises.

I & III. With direct transmission.
II & IV. With electrical transmission.

I.

Cost per B.H.P. hour at 25% Load Factor with direct transmission.

Works Costs.	125 B.H.P.	250 B.H.P.	500 B.H.P.	1000 B.H.P.
Fuel	0·25d	0·22d	0·21d	0·19d
Water (at 3/6 per 1,000 gals.)	0·05d	0·05d	0·05d	0·05d
Oil and Stores . .	0·17d	0·17d	0·16d	0·15d
Wages	0·23d	0·15d	0·08d	0·04d
Repairs	0·08d	0·07d	0·06d	0·06d
Management... ...	0·01d	0·01d	0·01d	0·01d
	0·79d	0·67d	0·57d	0·50d
Capital Charges: Interest and depreciation (together 7½%)	0·20d	0·16d	0·16d	0·15d
Total cost per B.H.P. hour	0·99	0·83d	0·73d	0·65d
Basis price per ton of coal of 9,000 B.Th.U. per lb.	14/-	13/6	13/-	12/6
Amount consumed per B.H.P. hour (Plant factor 75%—) ...	3·0 lbs.	2·75 lbs.	2·66 lbs.	2·5 lbs.
Thermal efficiency overall	12·75%	13·9%	14·4%	15·3%

II.

Costs per B.H.P. at 25% Load Factor with electrical transmission.

Total cost per B.H.P. hour	1·24d	1·04d	0.91d	0·81d

III.

Cost per B.H.P. hour at 50% Load Factor with direct transmission.

Works Costs.	125 B.H.P.	250 B.H.P.	500 B.H.P.	1000 B.H.P.
Fuel...	0·24d	0·21d	0·20d	0·18d
Water	0·05d	0·05d	0·05d	0·05d
Oil and Stores ...	0·16d	0·16d	0·15d	0·14d
Wages	0·23d	0·15d	0·08d	0·04d
Repairs	0·06d	0·05d	0·05d	0·05d
Management ...	0·01d	0·01d	0·01d	0.01d
	0·75d	0·63d	0·54d	0·47d
Capital Charges ...	0·10d	0·08d	0·08d	0·07d
Total cost per B.H.P. hour	0·85d	0·71d	0·62d	0·54d

IV.

Cost per B.H.P. at 50% load factor with local electrical transmission.

Total cost per B.H.P. hour	1·05d	0·88d	0·76d	0·66d

The conclusions to be drawn from comparing Tables A and B are the following :—

(*a*) That for fairly steady loads during ordinary factory hours (25 per cent. load factor), it is cheaper for the Power-User to employ his own engine applied direct —that is to say, without the intervention of electrical transmission—even below 125 H.P., which is estimated to cost 0.99d. per B.H.P. hour, and 1000 H.P. 0.65d. per B.H.P. hour against 1.06d. per B.H.P. hour purchased.

(*b*) That for ordinary factory hours, where the diversity factor would justify electrical transmission in any case, a private plant of 250 H.P. and upwards can compete successfully with the assumed purchased supply of energy.

(*c*) That for a 50 per cent. load factor a local 500 H.P. engine, applied to its load direct, would cost less than the assumed purchase of electric energy.

(*d*) That for a 50 per cent. load factor, when the diversity factor justifies electrical transmission in any case, a 1000 H.P. private plant (or larger) can successfully compete with the assumed purchased supply, after covering motor losses.

It will be noticed that the advantages of increased load factor are not so marked in the case of the private plant as with the public supply undertaking. This is due to the latter requiring in any case to employ staff for a 24 hours' service per day, whatever the load factor may be, whereas the private plant requires only one shift, so long as the running can be confined to ordinary factory hours.

The advantages of gas plant compared with steam plant, particularly for high load factors, are :—

(1) The thermal efficiency is approximately twice as high as in a steam plant, consequently only about half the coal is consumed for a given duty.
(2) The incidental and stand-by losses of a gas producer plant are less than in a steam plant.
(3) The water consumption of a gas engine and a producer plant combined is far less than with steam plant.
(4) The repairs required by producers are less than the repairs required by boilers.
(5) The attendance required for a battery of producers is less than for a battery of boilers doing the same duty in H.P. hours.

The disadvantages of producer gas plant are :—

(1) That—omitting types designed solely for the use of anthracite or coke—the capital outlay is somewhat higher than for steam plant of similar capacity.
(2) When constructed for the use of bitumenous coal they occupy more space than steam plants.
(3) They are not so well understood by the average attendant as the steam engines and boilers.

There is little doubt that with the increasing demand for large gas engines and producers, their costs will in the near future be materially reduced, whilst the one other disadvantage of importance, namely, want of knowledge of gas plant on the part of attendants, will quickly pass away with their increasing use.

The losses through radiation and condensation of steam in long ranges of steam pipes is sometimes enormous. There are factories using a number of scattered steam engines consuming an average of 15 lbs. of coal per B.H.P. hour, whereas there are no such losses from gas mains.

Just as it took ten years to establish the Parsons steam turbine, so may several years elapse before the use of producer gas for the development of power becomes general, but the author is convinced that the vastly superior thermal efficiency of the gas engine compared with the steam engine will certainly secure for it the most prominent place in the second stage of the "*Age of Mechanical Power*"—the stage of the Internal Combustion Engine.

SECTION D.

Archæology, Education, Mental Science, Philology, Political Economy, Sociology, and Statistics.

Section D.

PRESIDENT'S ADDRESS.

50—ECONOMIC WASTE.

By Arnold H. Watkins, M.D., M.R.C.S.

If the honour of being President of a Section entails the penalty of having to deliver an opening address, there is at least this compensation, that much greater latitude is usually allowed for the author of a presidential address than would be allowed to the reader of a paper dealing with any of the scientific subjects included in the scope of the section.

The reader of a scientific paper is expected to bring before you some new facts, some hitherto uncompiled statistics, some fresh theory to explain already recognised phenomena, to make, in fact, some addition to our scientific knowledge. A presidential address, on the other hand, does not necessitate the bringing forward of any new scientific observation, but is allowed by custom to deal in a much more loose and general way with the whole class of subjects comprised within the section, or with any particular subject at the reader's choice. Of the license so accorded I intend to avail myself to the full. I have no new facts to bring before you, I have no new interpretation of old facts to offer you, but there are, I think, certain aspects of well-known facts that are apt to escape our attention, and I am going to ask you to bear with me while I urge on you the importance of some of these.

I have taken as the title of my paper *Economic Waste.* There are doubtless many forms of economic waste, but the special one which I am going to talk about is the waste of human energy, of human force, the waste of productive power which is involved by our present industrial system, to say nothing of the misery that is entailed thereby. I have, as I told you, no statistics to lay before you, nor do I think they are needed. You all know, and are constantly being reminded by almost every newspaper you pick up, that a large number of people are always out of work—*unemployed.* The number varies according to the fluctuation of trade, but in greater or lesser number the unemployed are always there.

Now, no one would, I expect, deny that for the "out of work" himself this is an evil, but, looked at from the broader point of view, as it affects the community as a whole, the common weal, is it also an evil? To me, it seems quite clear that it is. If one-tenth, or even one-twentieth of your possible workers are unemployed, you are producing one-tenth or one-twentieth less of food or commodities than you could do if all were at work, while, seeing that those who are

contributing nothing to the wealth of the community, nevertheless have to be fed and housed and clothed (however unsatisfactorily) either in workhouses or by public or private charity, the wealth of the rest of the community which *is* engaged in productive work is always being diminished by the maintenance of those who are bringing nothing to the common stock. That is, there is Economic Waste.

Were it possible to deal with the people who have no work to do, and whom nobody seems to want, in the same way that our Municipality deals with unnecessary dogs, and send them to the lethal chamber, society would at least be relieved of the cost of their keep, but no one has yet, I believe, been bold enough to suggest this remedy. Moreover, there would be this drawback, that when trade improves again and more labour is required, you would have no surplus supply to fall back upon. You might shut up your lethal chamber, reduce the cost of marriage licenses, and do all you could otherwise to increase population, but the crop of able-bodied workers would take so long to produce that by the time it was available the next swing of the pendulum in the industrial world would have taken place, and you would again have to fall back on the lethal chamber.

Is there no means by which the overplus of labour, which the industrial condition of the country does not at any given time require, can be usefully employed at something else till the next expansion of commerce causes it to be again demanded?

If there be any such thing possible, three great ends would be attained.

Firstly, the community would be relieved of the cost of maintaining the unemployed.

Secondly, the workers so enlisted, in what I might call the industrial reserves, would be saved from the deterioration which seems inevitably to accompany idleness. Even machinery allowed to stand idle deteriorates; how much more human beings kept in idleness deteriorate every thinking and seeing man must admit. Whether it is, in the words of Dr. Watts, that "Satan finds some mischief still for idle hands to do," or whether we look for an explanation to the ordinary nature of things and men, without calling in the aid of His Satanic Majesty, is not very important—the really important fact is that when we allow any of our workers to be for any length of time out of work we are allowing our labour to deteriorate, so that if we do later on find employment for them, the equivalent of work that they will do will be definitely less than if they had been all along in steady work; so that again there is Economic Waste.

Thirdly. Yet again, if the thousands or millions of persons at any given time unemployed, and so producing nothing, could by any means be turned into producers of any things that the rest of the community (those in work) require, what an enormously increased effective demand there would be for the things already being produced. All these unemployed people *want* things; the demand for the commodities others are producing is already there; give them

the means of producing something they could exchange for those other commodities, and the demand, in the ordinary sense of the word, would become an "effective" demand in the economic sense.

One of our greatest concerns as a State is the discovery of new markets for our products, or the retaining of those markets we already have, and nearly all the wars of modern days have been trade wars. Whatever the ostensible reason for war may have been, go right down to the root of it, and you will find it has been the desire to create new markets, or, at least, to retain old ones. It seems to me clear that in our unemployed we have at our very doors a huge market still unexploited if we could only turn them from mere idle consumers into active producers. Is it not possible to do this?

Some people will tell you that it is impossible, that the condition of these people is due to over-population, the result of natural laws, against which man is powerless. If all the material in all the world were being worked up, if all the land were being cultivated to the full, it might be impossible to find anything for the unemployed to do, and we might have to seriously consider the lethal chamber. But *pace* Malthus and his doctrine, this state of things has not only not arrived, but its possibility is so far off that it need no more be considered than the eventual cooling of the earth, or the disappearance of its waters need be. There is still abundant land on the earth's surface which is not cultivated, and which could be cultivated; not one tithe, I imagine, of the food which the earth could yield, if it were required, is at present produced; raw material for manufactures is in excess of the demand for it, and could be almost indefinitely increased if it were worth while; so that it is clearly not the parsimony of nature which is at fault. Nature still responds generously enough to man's labours, and even if at some times and in some places she requires more labour than at others, one would think that this should make the demand for labour greater, and not less, make it all the more important to have our whole population usefully employed, and no idlers whatever, enforced or otherwise. So that, looked at from the broad standpoint, it seems to me clear that over-population is not a factor in the problem. If all the resources of nature were exploited to the best advantage, the population of the world might be increased enormously before it came in any way to press on the means of subsistence.

Nor do I think it is the need of capital. At the very time when the greatest number of men are out of work, you will often find the greatest amount of capital lying idle—show it how to find a profitable investment, and the capital is readily enough forthcoming. It is just this factor of the investment being *profitable* on which the whole problem seems to hang, and as long as we take no broader view of what is good for the human race than we do at present, and leave the whole question of whether a large part of the race shall be idle or at work to be determined by the direct interest of a comparatively small number, I see no hope of a solution of the problem. Good trade, the possibility of profitably investing capital, may for a time remedy things, and work for the unemployed become for a time

plentiful, but it will only be for a time, and the inevitable swing of the pendulum will again throw hundreds of thousands out of work, and the Economic Waste begin again, with the inevitable deterioration, moral and physical, of the workers, which, as I have pointed out before, idleness brings in its train.

Is there no remedy? Is it one of the inevitable evils to which the human race is doomed, and from which there is no escape, and which increased civilization only seems at times to accentuate?

I will not pause to enquire how, if it were so, anyone could believe that this world of ours is the creation of a beneficent Deity, and governed by wise and kindly laws, because, though in our churches and on the Sabbath Day we devoutly recognise the Deity and profess the Christian faith, any appeal to the doctrines of Christianity as a working basis for practical life is as futile in the case of the nominal Christian as in that of the avowed atheist; but, keeping strictly to the Economic aspect of the question, I say unhesitatingly that escape *is* possible, that it is not the laws of nature, but the conventions of man, that are responsible for the waste and the misery it entails. It is partly, no doubt, our selfishness that is to blame, but it is, I think, still more our ignorance and our narrowness of view. The old *laissez faire* policy has been tried and found wanting. Can we not substitute for it any better system with happier results?

Now, you will say it is easy to raise a question such as this, and to point out evils and defects, but have you anything practical to offer as a solution of them?

Not much, I fear. I plead equal ignorance with the rest of the world, but the first step towards knowledge is to recognise our ignorance; we have gained something when we even recognise that we do not know a thing, and if from that we go on with a resolute determination to find out all we can about it, some day, somewhere, somehow, the solution may be found.

To me, it seems almost self-evident that the individual is powerless to remedy this evil, that the combination of at least a whole nation, what we commonly call the State, must in some way be called in to help—possibly the solution cannot finally be found till we have a combination of States; but I think some advance might be made by modifying our system of leaving all industrial affairs to the individual, and at least experimenting in the direction of State interference on behalf of the unemployed. We are told it is not the business of the State, and we are told this by such good authorities that I feel most diffident in daring to assert otherwise. Nevertheless, I do so assert, for it seems to me that the question of the unemployed is most essentially the business of the State. No one disputes that the protection of our trade and of our industries is the proper business of the State; no one disputes that the encouragement of our trade and of our industries, by such means as the provision of good harbours, of easy and safe means of communication, and so forth, is the business of the State; no one disputes that the providing of at least a minimum of food and shelter for the

destitute is the business of the State; few people dispute that the care of the public health, the protection of the individual against violence, either intentional or through negligence; the provision of education, whether elementary or advanced, is the business of the State. Is it, then, too much to assert that the provision (if it be possible) of work for the unemployed, for those for whom private enterprise finds no use, is also the business of the State? That it would have to be undertaken with care goes without saying; what is wanted is, I think, to deal with the residuum, not to revolutionise the whole industrial system, and great care would be needed to find employment for the residuum without disorganising the whole of our industries. Nevertheless, I believe it could be done—I believe such work could be found that, while it provided in the end a valuable increment to the nation's assets, no injury was in the present inflicted on the rest of the nation, except, perhaps, a temporary increase of taxation, which would be almost met by the relief from high poor rates, and the necessity for private charity which now exists.

It is objected, and sometimes rightly objected, that for the State to turn producer would be to seriously and unfairly interfere with other producers. Take in a small way, for instance, goods produced with convict labour. If prisoners in gaol make brushes or mats or any articles of that sort, the sale of such goods is unfair competition against other manufacturers who employ free labour. If the State were to undertake to find work for the unemployed in England by hiring or buying land and putting all the unemployed to raise wheat, it is conceivable that it might lower the price of wheat all round, and so affect the wages of those at present in work, or throw more of them out of work, and so increase the very evil it was intended to cure. Despite Carlyle's forcible asseveration that with thousands of bare backs it is absurd to talk of over-production of shirts, as a practical matter the manufacture by the Government with unemployed labour, of shirts to cover these backs might very seriously interfere with the legitimate and normal industry of shirt-making, and have disastrous results. The problem, then, is to find some method in which the waste labour of the unemployed might be turned to useful account without disorganising industries which are at present beneficially employing a large amount of labour. Now, I do not believe this is impossible, even in England, though the problem there has reached huge dimensions. Surely there are some things like harbour works, road improvements, water conservation, drainage of waste land, redemption of ground from the sea, and so on, which might be undertaken in order to provide work when other work is not obtainable, and which, in the end, would yield a very considerable asset to the national wealth without in the meantime in any way interfering with the normal industries of the country. Labour so employed would form a most valuable industrial reserve, from which workmen could always be obtained when the condition of other industries rendered more labour in them necessary, as public works of the kind I have indicated could easily be abandoned for a time whenever, or if

ever, there were sufficient employment elsewhere—to be resumed again when a surplus of labour again occurred. Both employers and employed would be benefited by the establishment of such industrial reserves.

But it is perhaps not our business to teach *England* how to manage her affairs or how to deal with her unemployed, so I will not pursue that any further. It *is* our business to put our own house in order and prevent the evils of extensive pauperism in this country, if it be possible, and it is to the South African aspect of the question that I shall devote the few remaining words I have to say.

Till comparatively lately there has been but little real poverty in this country; the demand for labour in a new country is usually greater than the supply, and except for the complication introduced by the race problem, there would probably have been, and still be, plenty of work for everyone. Still, even here the "Poor White" is not a product of yesterday, and I fear, unless we can find some sound means of dealing with him, will not be a thing of the past to-morrow. Moreover, we are developing, nay, I fear, have already developed, a loafer class very nearly akin to the class we all know well at Home. Some of you will perhaps say, "There you are, that is the impossibility of the problem. The Poor White is ignorant and lazy, and will not do manual work or let his children, because that is Kaffir work and beneath the dignity of a white man—while as to the English loafer he is just as hopeless." Yes, I am afraid you are quite right if you look only to the full-developed specimen. I doubt if your well-matured individual Poor White, or your thoroughly-developed loafer can be reclaimed, but there is always this comfort about him, that though you cannot even get rid of him by means of the lethal chamber, time will get rid of the individual all right by-and-bye; it is not the cure of these wasters that is the important thing, it is to see that you do not go on manufacturing more and more of them. The Poor White and the loafer, though perhaps both incurable, are, unlike the poet, made, not born; they are the direct result of the circumstances under which they exist. Alter the environment, change your system of dealing with the children, and you will find them grow into very different adults.

How is this to be done? Education is the panacea generally advocated, and I should certainly be the last to disparage education. But the teaching of the three R's, or even the rudiments of classics and mathematics is not going to solve the problem. What you need is work; there and there only lies the solution. Is it then possible to find work for these people on the lines I have already indicated? That is, work which in the end will produce an asset to the country equivalent to, or, at least, approximately equivalent to, its cost; work which will not interfere with the industry of those already employed; work which will not be unnecessarily costly by requiring a large expenditure on machinery or plant in addition to the wages paid out; work which is not derogatory to the dignity of a white man?

I think it is possible. We have in this country abundance of *unused* land, though, I regret to say, little *unowned* land; we have abundance of water running away uselessly every year; we have already a large number of unemployed. Surely here is Economic Waste! Waste land, waste water, waste labour; bring the three together, and we shall be a long way on the road towards solving the problem of what to do with our Poor White population, what to do with our out-of-works who have not yet degenerated into hopeless loafers. A few well-considered schemes for conserving water would employ a large amount of labour with comparatively little expense for materials or machinery. It is work that any able-bodied man could do—it is work that even the Poor White who is not yet fit only for the lethal chamber, I believe *would* do, if you so arranged things that he was not asked to work along with Kaffir labour. I have seen plenty of poor Dutchmen working hard at dam-building with no one but their own sons to help them, and if they will do this on a small dam they would do it on a big one, too. You could justly hold out to them the hope that if they would work honestly at the irrigation works they should have an opportunity of hiring such portion of the land to be eventually irrigated as they could work with their own labour—some small amount of their wages possibly being retained as deferred pay to help them later in starting for themselves as peasant cultivators. Doubtless, in addition to the original cost of the work for conserving water, and the purchase of suitable tracts of ground for irrigation, some expense would have to be incurred in nursing your colony of peasant cultivators for a time, and doubtless it would be a long time before any adequate return could be secured from the capital so invested; but with wisdom and patience and a proper understanding of the right way to give out such ground, so as to secure a fair return to the cultivator, while securing to the State a fair share of the ultimate benefit, I believe in the end the State would reap a substantial advantage. This ultimate advantage, too, would be quite apart from the immediate benefit of saving our waste labour from steadily deteriorating as well as increasing and becoming a terrible incubus on the whole community. Time forbids my saying more about the system of tenure that would be advisable, than that probably a modified "metayer" system, with the State retaining the title to the soil, would be the best.

There will, of course, be endless objections to this suggestion, which I cannot possibly attempt to answer in this paper, but two difficulties which will rise at once in many people's minds I must deal briefly with.

The first of these is, What are you going to do with your produce? Where are your markets for it? You cannot grow vegetables for Johannesburg or Kimberley unless you are close to the railway line, and if you could, you would only flood these markets and ruin the people who are already supplying them. You cannot grow corn, because it will cost you more to do so on your irrigated lands than you can import it for from abroad! Granted, but you can do

something else altogether with your ground. Everyone who knows this country at all, knows that if artificial food could be obtained at a reasonably low price for some three or four months in the year, the amount of stock the country would carry could be easily doubled. Let any farmer now attempt to put on his farm as much stock as it will carry in the best part of the year, he will lose half of it by sheer starvation when the winter comes on or when the dry season is unusually prolonged; find him fodder for a few months, and he might safely double the amount of his stock. I am not simply theorising, though I am no farmer, for the experience of England has proved this clearly enough—with the introduction of root crops for winter fodder, farms in England were enabled to carry a very much larger amount of stock than had previously been possible, and the same result would unquestionably follow in South Africa if artificial feeding for part of the year became practicable. Whether the crop to be raised on the irrigable lands I have advocated should be root or lucerne or what, is not for me to say—that is a question which would soon be solved. But that a market would be readily found for the produce is, I think, clear enough, while an enormous advantage to the whole country would accrue from the increased amount of live stock, which could be reared and maintained.

The second difficulty is the cost. "Sheer nonsense," I can hear some people say, "with the country verging on bankruptcy to even suggest such a thing—of course, it is impossible." If I were seeking a seat in Parliament I should perhaps be ill-advised to put the suggestion in my election address, or to expatiate on it from the hustings, but I trust that an Association for the Advancement of Science is capable of taking a broader view of things than the average elector, and of looking farther ahead than the ordinary ratepayer. It is just when a country is at its worst that it is most important to take stock of its assets and see if the best is being made out of them that could be done. Are we making the best out of our waste land, out of our waste water, out of our waste labour—are we even making the best we can out of our grazing ground? If we are not, should we not then seriously consider how we can use them to greater advantage? Suppose such a scheme as I have indicated did mean some increased taxation for a time, could we not possibly stand it, even hard up as we all are? A little less whiskey, a little less tobacco, a few less nights at the theatre, a star or two less on tour from England, a few less new dresses for our wives, our own dress-suits or tall hats a little less up to date—would any or all of these things be impossible to bear if we felt that the ultimate good of the whole country, and the immediate salvation of our destitute poor, demanded it of us?

If we had to face a costly war to save our Colony or the Empire from danger, we should not hesitate about the cost; can we not face the cost for such an object as I have indicated? Or was I right in my pessimistic suggestion that most wars were not philanthropic or patriotic, but commercial? And even if I was right, surely if we can face the enormous expense of war for commercial reasons, we

should not shrink from the cost of a peaceful experiment which, if successful, would bring with it more blessings and more prosperity than the most successful war.

I have finished, because my time, not my subject, is exhausted. You may disagree with every word I have said, you may disprove almost every statement I have made, but you cannot get away from the fact that this problem of what to do with our unemployed is one of the most important, if not *the* most important, problem with which we have to deal. And as such I make no apology for thrusting it before you and saying think about it, look at it fairly and earnestly, and see if nothing can be done. The gold output, Chinese labour, the Customs tariff, the prospects of the share market, may be of extreme interest to some of us personally, but the problem of the unemployed is one which affects us all, and on the solution of which the prosperity or otherwise of unborn generations depends. Many of the greatest advances made in the last century, and particularly in the latter half of the century, have been due to the discovery of the means of utilising various waste products of industry. It is for this century to find the means of utilising that waste product of our industrial system as a whole, "unemployed labour," and so put an end to the misery and degradation, almost inevitable for those who are "out of work," as well as to the present enormous Economic Waste.

51—NATIVE EDUCATION IN ITS HIGHER BRANCHES.

By K. A. Hobart Houghton, B.A.

The subject of native higher education has been brought prominently before the public of South Africa through the movement to convince the Governments of the various Colonies that the natives of this country are anxious for the establishment of an inter-State Native College upon the lines of the recommendation of the inter-Colonial Native Affairs Commission.

The need for some action on the part of Government to assist what, after all, is merely the natural development of a century's educational work is receiving recognition in most quarters.

Once the duty of the State to foster higher education, and the principle of giving educational facilities to all who are able to take advantage of them—whatever their race or colour may be—is admitted, it only remains to establish the necessity for an immediate advance, and the present proposals are fully justified.

The argument in their favour is based upon the pressing needs of the natives themselves and the welfare—intellectual, social, political and economic—of the whole country, both of which call for action in the not too distant future.

The better to realise how deep and widespread are the natives' actual wants in the direction of better or higher instruction, a brief outline of the progress and present position of native education may help.

The early years of last century saw the beginning of a school system for native children. It was the work of Christian missionaries, and has ever since been carried on by them. For fifty years the Church alone bore its cost before the Government assumed a share of the responsibility, and during the last thirty years the natives, the Governments and the Churches have contributed to its upkeep.

The initial difficulty of creating a demand for so unsubstantial a commodity as education gradually lessened and the number of schools grew beyond the control of the European teachers; so that in 1841 the first school for the training of native teachers was established at Lovedale, and was soon followed by others belonging to the various religious bodies.

The object of these institutions was to further the more directly evangelistic efforts of the Church, and this intention, while perfectly natural and understandable in the circumstances, carried out in all native educational work, with its consequent tendency to subserve the interests of education to those of the Church's work, has had an effect not altogether beneficial to intellectual advance.

To Sir George Grey is due the honour of recognising the value of industrial training in the civilization of the Bantu—a discovery which the Moravian Missionaries had made years before and utilised in their work among the Hottentots. At his suggestion and with the help of his Government several of the missionary institutions opened industrial departments. Partly owing to lack of continuity in the Government policy towards this kind of work, partly to the disfavour with which the home supporters of missions regarded what

seemingly had so little connection with spiritual work, but chiefly owing to the costly character of the work itself, many of these schools had to be abandoned. But in the one or two instances where the work has passed through its experimental stages and has established itself in the favour of natives and Europeans, its economic and educative value has been so fully demonstrated as to justify, in the opinion of those who have studied its results, the heavy expenditure it entails.

Thus it will be seen that there are three classes of mission school supported by Government, the elementary, the industrial and that for the training of pupil teachers.

But one of the natural results of all these years of labour has been the creation of a small and steadily increasing class of native students who aspire to, and are capable of, higher courses of instruction than these schools afford. Out of the hundred and fifty thousand pupils in school, one might expect that at least one in every thousand who start on the path of knowledge might like to pursue it past the sign-post known in this country as Standard VI. And Government makes no provision for them. One or two of the older institutions may attempt to meet the demand. Under present conditions, however, neither arrangements nor results can be called satisfactory; teacher and pupil labour under difficulties which only a re-modelling of the whole system can remove. Besides this, the expense of such classes —no Government grant being obtainable—is out of proportion to the income of the institution, and were it not that their existence keeps open to natives the door to the higher branches of education, seems hardly justified by the results. To take one instance: In the College Department at Lovedale about fifty students are being prepared for the Matriculation and School Higher Examinations of the Cape University, at a cost of something like £750 a year, very little of which is covered by native fees.

That the desire on the part of a few for better education is more than a mere vague ambition to obtain something which they do not possess, is evidenced by the fact that a considerable number have already gone to Europe and to the Negro Colleges of America for that type of education they are unable to get here. No doubt many go to these Colleges who cannot possibly benefit from a genuine College course, and there may be a political significance attached to the movement. But the exodus to America is a fact, and, viewed from whatever point, can hardly be called desirable.

There is also a pressing need for better trained teachers to take charge of native schools. It is undoubtedly true that a difficulty is experienced in trying to keep pace with the rapid growth in the number of schools, with any kind of teacher, trained or untrained. But the best type of native youth is at present being lost to the teaching profession, though he may be trained for it. It is not sufficiently attractive. Interpreters and Clerks—even policemen and miners—are paid better than teachers. Nor are the majority turned out by the training institutions worth more than they get. The most pressing need of native education is not more teachers of the

present type, but a few really educated and specially trained men. By attempting to meet it the *status* of the whole body of teachers would be raised, their career made more attractive, and the general supply increased. There are many acting teachers who would gladly enter a higher grade course, were such opened to them.

Behind all this there is the indefinite, but widespread, desire of the natives to obtain for the younger generation that "knowledge" which they recognise has helped the white man to his present position of superiority. This leads one to point out briefly the intimate connection between the present movement in favour of a State-controlled Native College, and the future general welfare of the country.

A highly developed civilisation has come with the force and rapidity of an avalanche upon the Kafir living in his kraal. But it has not overwhelmed him. He is possessed of sufficient strength to assimilate it. But coming as it does, and finding him as he is, the period of assimilation is fraught with the greatest dangers. New forces have been released among the people. New hopes, new ambitions are stirring them. What the ultimate issue will be, it is difficult to say. The points at which friction between Europeans and natives is possible are rapidly increasing. The two races are drawing nearer to one another before a mutual sympathy and understanding are sufficiently assured. It is therefore all important that the leaders of the native van should be men of wide sympathies, understanding European modes of thought, and recognising that the interests of either race are inextricably bound up with those of the other. The natives in recent years have given abundant proof that they intend advancing under the leadership of men of their own race. It will be the highest work of the proposed College to train such men who, by force of character and intellectual attainment, will worthily lead. Even the most enthusiastic negrophilist has little to say on behalf of the semi-educated native, whose bumptiousness and self-assertiveness are so much in evidence in our towns, except that he is a necessary evil of the present phase in the evolution of the Bantu. But unless something is done, this class, which must rapidly increase as time goes on, will continue in the ascendancy and provide leaders of the type that has already worked so much mischief. It is hardly an exaggeration to say that the proposed College will have opportunities of shaping the destinies of this country greater than were ever given to an educational institution. Dr. Booker T. Washington, after twenty-five years work at Tuskegee has, in the opinion of American statesmen, pointed to the solution of the negro problem there. It remains for an inter-State Native College to do the same for South Africa, though the problem is different and more complicated.

In view, therefore, of the possible establishment in the near future of a native college under the control of the several Colonial Governments, it is important that educational thought should be focussed upon questions affecting the policy of the Institution. This will be seen to be all the more necessary when one remembers the

influence that such a College will exercise on native education generally, and the opportunity thus afforded of arriving at some common basis of educational policy for the whole of South Africa. How much this is to be desired all students of the subject can testify. For while in most countries it is accepted as a guiding principle that education should be framed to meet the social and economic requirements of the people for whom it is intended, native education in some, at least, of the older South African Colonies has not been so dealt with. The same course of instruction, the same system of examination, is devised for both black and white. No account is taken of the difference of language, of environment, of future position in the country. With delightful frankness the Cape Education Department in an article appearing in the *Education Gazette* of April 1st last, alludes to its policy in the following terms: "The native population is the problem of Africa; and the crux of that problem, if it is rightly considered, is the question of the proper educational policy to pursue. In Cape Colony this question was never formally dealt with. The early missionaries, who of course were not educationists, felt first the need for teaching reading to the children of their converts, and having begun this added in time a little of the other R's. As for the State it may be said to have simply refrained from interfering. As a consequence of this *policy of drift* two general principles came to regulate State action in this matter; first, that all native schools should be under the management of one of the missionary societies; second, that the instruction given should follow the lines of the elementary course prescribed for European schools, but that no assistance should be given in aid of work higher than the fourth standard, except in the case of candidates preparing for the teaching profession."

While it is true to speak of the College as a natural development of the work carried on by existing institutions, in another sense it is a new venture, an experiment which must be conducted under the most favourable circumstances and by men unfettered by tradition. To this end the co-operation of all the States is desirable, who should nominate a Governing Council independent of the control of their respective Education Departments.

All courses of higher work must at this stage in the development of Native education be tentative and so framed as to be capable of reconstruction again and again if necessary. At the same time some who have closely studied the subject, and have had unique opportunities of making experiments in it, have arrived at a few guiding principles which may be found to be of general application to all native education. They are briefly stated here in the hope of their being tested in a wider field of educational thought than they have yet entered; and with more confidence than would otherwise be justifiable, since they have been thought out independently, and applied with practical results in the native school system of Central Africa, which affords instruction to over sixty thousand children.

The first of these is, that a curriculum of native higher education should be framed, not only to meet the present needs of

the people, but also with an eye to their future. This means that the ultimate standard and ultimate aim of native education must be the same as that for Europeans. In a country circumstanced as South Africa is, there cannot with any safety exist two ideals of civilization. Sooner or later they would be bound to clash. The European and Native child have different starting points and may require to travel for some distance by different routes. This will probably be the case with the majority for many years to come. But these roads must converge, they can never be parallel. In framing therefore what would develop into a full "Arts" course one should remove the disabilities under which the native at present labours owing to his language. By having to work in English, which is to him a foreign tongue, and will continue to be so for centuries to come, and having to force his way through the medium of this foreign language into all the mysteries of Latin Syntax before he can establish himself upon the path of a College training, he is hopelessly handicapped. This alone accounts for the failure in the past of the majority who have attempted to attain to the *status* of a University Student. If this College is to aim at leading native students to the standard of attainment required by a University, there will have to be a widening of the existing approaches to the Degree examination in South Africa.

Nor is this necessary only because of the language difficulty. On account of his past, with its inheritance of grossness and superstition, and on account of his environment and lack of early training, there are certain lines of study which are of far greater importance in the education of the native than in that of the European. Indeed they may be said to be essential. Nothing but a constant appeal to nature and to the unvarying truths which determine the phenomena of nature will eradicate the native's deeply rooted belief in witchcraft, which is perhaps the greatest obstacle in the way of his advancement, intellectual and moral. In other words, general science in all its more important branches—Natural Philosophy, Chemistry, Botany, Zoology, Geology and Astronomy—would have to form part of any liberal course of education.

For the same reason, if we are to produce really educated men, that is, men fitted for the duties devolving upon them as leaders of a race emerging from barbarism, and if we are to develop their highest usefulness, a carefully planned and progressive course of manual instruction should be given side by side with the literary studies. As training for the hand and eye, from a health point of view, and in creating and strengthening moral character it would prove invaluable. But it is in the after life of the student when his example as a civilizing agent amongst his own people is needed, that its full benefits will be seen.

In one other direction native higher education may have to differ from that given in the average European University. It may not be the duty of the State to provide for the religious training of the young, but few will deny that it is the duty of those responsible for native education to make every provision for the moral

training of the student. We cannot afford to reproduce Frankenstein's creation in South Africa. And in the present stage of their development the teaching of ethics cannot be divorced from religion, nor a moral character produced without reference to an Unseen Being. Not that the questionable dogmas of the Churches should be perpetuated, but that the native student should learn the secret of all moral victory from the example and sympathy of men with high spiritual ideals.

Yet another principle that should guide in the framing of a native college course is that, while the education provided should aim at the widening of the student's mental horizon and the deepening of his intellectual capacity, it should after a certain point lead in the direction of specialised training. Whatever "Arts" course is framed should be followed by courses with distinctly professional and utilitarian aims. We want to produce a class of men who can turn their education to practical use in the work of uplifting their own people. There are at present openings for such, whether trained as better class teachers, or as agriculturists, or in the direction of sanitary reform. Indeed it is questionable if, at least for some time to come, a degree should be conferred upon any native student who has not successfully completed some such professional course.

Such, briefly stated, are the aims of the present movement towards an extension in native higher education in the form of the establishment of an inter-State Native College. The College is certain to come. It rests with those who guide the educational thought of this country, so to shape its policy, that its highest potentialities may be realised.

52—SOME POPULATION FIGURES.

By J. M. P. Muirhead, F.S.A.A., F.C.I.S., F.S.S., &c.

For many years a body of men have come together in Great Britain annually to discuss the Advancement of Science, and now in South Africa this particular Association has been formed for the same purpose as the parent one in England, and I sincerely trust that it has a long life in front of it, and that it will be productive of considerable benefit not only to its own members but to the whole of this vast Sub-Continent.

Of all the branches of science which are likely to be discussed at the meetings of this Association, Statistics is probably the one which will arouse the least interest, and yet it is in many ways the most important.

I think it will be generally admitted that the most important discoveries in science have been the reward of careful measurement, and unwearied labour in sifting numerical results. Indeed, I might go so far as to say that Statistics form the foundation on which many other scientists work, and without which they would fail to be eminently successful. As Major Craigie, in his Presidential Address to this Section of the British Association, held at Bradford in 1900, stated: "We are the hewers of wood and the drawers of water for the economic controversialist of the day"; and Lord Kelvin says that "Measurement and comparison are the essential conditions of any form of significant discovery in the domain of science," and the statesmen who sway the destinies of the country, and are guided by certain accepted theories which have been arrived at by the study of certain facts in life by the Statistician, must recognise that it is essential that the information on which they found their policy be absolutely accurate, and the figures supplied reliable. And, therefore, the Statistician becomes an important element in the Government of a country, and it is of vital import that he approach his work not only in a scientific spirit, but in one recognising the importance of what he is doing, and fully grasping the necessity for the most absolute accuracy in all his work.

It is hardly necessary to irritate you at this stage with an academic enquiry into the origin of the term "Statistics," and whether it is the duty of Statisticians simply to collect and present facts and figures and hand them over to other scientists to deal with, or whether the Statistician is allowed to go further and frame deductions on the figures he has compiled. Major Craigie, in referring to the previous view in his Presidential Address to the Royal Statistical Society in 1902, stated "he had the authority of the late Dr. Engel for declining this strict definition of our science, as he had himself discovered in the writings of different authors over 180 different definitions."

There are so many interesting and valuable Statistical questions that might with advantage be placed before this Section that I have found some difficulty in deciding which to take, but there is no question whatever that the study of the numerous interesting details

concerning population has always been regarded as the most useful, the most valuable, and the most prominent field of Statistical enquiry, and therefore, as a humble student of that great and important science, it seems to me wiser, and with all modesty, to collect a few general figures, and also a few figures of local signification on this subject, which I may, for the first time I appear before you, deal with as likely to be not only of general interest, but possibly of permanent value.

I will therefore refer briefly to some features dealing with European population, and then deal with some purely affecting the Cape Colony. I may overstep the bounds of the legitimate Statistician by pointing a moral to adorn my tale, but I hope that may be forgiven, though the main object of my paper is more to present the figures, leaving others to point the morals; in fact, to be the hewer of wood and the drawer of water for those whose own scientific enquiries so fully occupy them that the Statistical foundation must necessarily be provided.

In referring to Statistics of European population, I may point out that the subject is so large that the figures of each country would require a separate paper, which would be full of interest, and therefore, with the exception of brief reference to some population questions of the British Isles, I can only simply point out the alteration in the importance of countries, caused by the increase of population during the last hundred years or so.

When we look back one hundred years to 1806, how important France loomed in the politics and history of the world, and countries like Italy, Spain, Holland, Sweden, Denmark, had also to be seriously considered as European Powers. To-day, however, we look at the population of the principal countries in Europe, and we must also take into consideration that great Western Power which has practically sprung up during the last century, viz., the United States, and we find that, in the first place, the population of Great Britain has increased during the period mentioned from 16 millions to 40; the population of Germany from 20 millions to 55; of Russia from 40 millions to 135; and of the United States from 5 millions to nearly 80. On the other hand, France has only increased from 25 millions to less than 40; the population of Spain is to-day under 20 millions; the population of Italy about 33 millions; the population of Denmark about 2½ millions; of the Netherlands a little over 5 millions; and of Sweden a little over 5 millions.

It therefore appears that, leaving out the question of the United States, there are only three European Powers who will be worth considering in the course of the next century, if they increase in the same ratio as in the past, viz., England, Germany, and Russia. France will be deposed from her present position by reason of the fact of her population being stationary, as it is surely obvious that population is the backbone of a civilized nation's power. And, in addition to the three European Powers mentioned, the other great World Power is obviously the United States.

I have not time at present to go into the question of Eastern nations like Japan and China, as it would make this paper too long, though there are some very interesting questions involved, but at present I merely point out the growth of population during the last 100 years, and what seems the inevitable deduction if it continues in the same direction, as everything at present indicates.

The population of England and Wales in 1801 was just under 9 millions, and in 1901 32½ millions, the average increase per cent. during each decade for the whole period being 13.85. For the exact figures see Annexure "A." In Scotland the population in 1801 was 1,600,000, and in 1901 just under 4 millions and a half, the average increase per cent. in each decade being 10.79. In Ireland the population in 1821 was 6,800,000, and in 1901 under 4½ millions.

In the last 20 years the total emigration from the British Isles has been over 4 millions, but in 53 years 4 millions emigrated from Ireland alone, which accounts for the extraordinary and somewhat sad state of the Irish population, which at the present moment is just about half what it was 60 years ago, when it was at its maximum.

For the purposes of comparison with the foregoing figures, it is interesting to note that the population of the United States in 1800 was 5 millions, and in 1900 75 millions, showing an average percentage increase each decade of 30.70. See Annexure "B." When one attempts to compare the United States with Great Britain and Ireland, one, of course, is at once faced with the difficult questions of immigration and emigration, and it is not within the scope of this paper to discuss these questions at any length. But the United Kingdom has lost population obviously through emigration, and the United States has gained very largely from immigration. Probably the large majority of the 4 millions Irish who have emigrated in the 50 odd years referred to went to the United States, and, indeed, that country has benefited to the following extent during the decades mentioned from immigration, viz. :—

From	1840-1850	27.9 per cent.
,,	1850-1860	31.5 ,, ,,
,,	1860-1870	35.0 ,, ,,
,,	1870-1880	24.2 ,, ,,
,,	1880-1890	42.1 ,, ,,
,,	1890-1900	29.4 ,, ,,

It will therefore at once be seen that the immigration to the United States has been enormous. Another consideration to be borne in mind in regarding its population, as compared with Great Britain's is that from time to time it has by annexation added to its population, as have Russia and Germany, and that, therefore, it is unfair in every way to compare the population as a whole, and were it the object of this paper to compare the growth of population in the United States with England, the Birth and Death Rates would

constitute the only fair basis, but I am merely quoting these figures as matters of interest, and to be borne in mind when I venture on the more important question to us of how the Cape Colony compares with the Australian in respect to population.

Before, however, leaving the matter of Growth of Population in Great Britain and Ireland, the question may arise as to the larger increase in England and Wales, as compared with Scotland proportionately. Looking at the Birth Rate, I find that the Birth Rate of the five largest Scottish towns is 28.2 per cent., as compared to 30.5 per cent. in the five largest English towns. The Death Rate, on the other hand, in the five largest Scottish towns is 18.5 per cent., while in the five largest English towns it is 19.7 per cent. The excess, therefore, in England is 10.8 per cent., and in Scotland 9.7 per cent., an apparently small difference, yet, when the numbers of the respective populations are borne in mind, the annual difference is very material.

Turning to the five principal Irish towns, we find that the Birth Rate is 29.7 per cent., and the Death Rate 20.7 per cent., so that the excess in Ireland of Births over Deaths, taking the five principal towns as a test, is only 9 per cent. per annum.

I have quoted the excess of Births over Deaths of Scotland as 9.7 per cent. in 1904, as revealed by the five principal towns, and of England as 10.8 per cent., yet the actual increase in the whole of England and Wales for the 10 years ending 1901 was 12.17 per cent., and the average for the century 13.85 per cent., so that it is evident that the figures of the five principal towns taken for 1904 do not altogether give an accurate result as applied to the whole country. In Scotland the increase for the 10 years ending 1901 was 11.09 per cent., and the excess in the five towns in 1904 was 9.7 per cent., thus also showing that the increase is really greater than as revealed by the test I have applied. But I am inclined to think that the Scottish figures are also reduced more than the English by emigration, though in 1904 Scotland's excess of Births over Deaths is actually slightly higher than England's. I have been unable to get them separately, as in the works of reference at my command the British Isles and Ireland are kept separately, but not Scotland and England, and it would be interesting to know how much of the difference in increase of population of the two countries is caused by emigration. In Ireland the excess of Births over Deaths per cent. per annum was in 1904, as shown by my figures of the five largest towns, only 9, yet the total is really only 4.84 for the whole country, showing that the population of Ireland is not only suffering from emigration but from other causes as well, of which the principal is the high Death Rate.

In turning to Australia, we find that the population was some 6 thousand in 1801, and, roughly, 5 millions in 1901. The annual increases per cent. are somewhat remarkable for the decades, showing an increase of 11.30 in 1861, and 3.13 in 1901. For actual figures see Annexure "C." This I put down entirely to decrease in immigration, as from 1851-1861 was the period of the gold fever, when

the emigration to Australia was very large indeed; the population increased in these 10 years from 430,000 to 1,253,000. A great deal has been said of late years of the slow increase of population in Australia, and in more than one quarter it has been stated that the Birth and Death figures were alarming, particularly the Birth figures, which showed that the increase was not as large as it should have been. Where this idea has been got from I find difficulty in understanding, as the following figures will very clearly prove.

The Birth Rate in the different Australian Colonies is as follows :—

West Australia	29.30
Victoria	26.39
Tasmania	28.94
South Australia	26.55
Queensland	29.81
New South Wales	28.20
New Zealand	26.16

or a total average for the whole of Australasia of 27.91.

The figures for England as a whole are 29.15, and for France 22, though Germany shows the high Birth Rate of 35.88.

It is difficult to see cause for alarm in the Australasian Birth Rate, though in new colonies the Birth Rate should really be higher than in old countries, because the proportion of very young and very old people is so much less.

Turning to the Australasian Death Rates, we find the following figures :—

West Australia	14.64
Victoria	13.43
Tasmania	11.97
South Australia	11.62
Queensland	12.31
New South Wales	11.87
New Zealand	9.87

or an average for the whole of Australasia of 12.53. This compares exceedingly favourably with

Italy	23.37
Germany	21.47
France	20.90
Ireland	18.03
Scotland	17.78
England	17.21

and would certainly give the impression that the Australasian Colonies are exceedingly healthy.

When one, however, turns to the excess of Births over Deaths in 1904, one finds:—

Germany	shows	per	thousand	...	14.41
Scotland	,,	,,	,,	...	11.97
England	,,	,,	,,	...	11.94
Italy	,,	,,	,,	...	10.87
Ireland	,,	,,	,,	...	4.84
France	,,	,,	,,	...	1.10

and then turn to Australasian Colonies, and what do we find the excess to be:—

West Australia	14.66
Victoria	12.96
Tasmania	16.97
South Australia	14.93
Queensland	17.50
New South Wales	16.33
New Zealand	16.29

or an average for the whole of Australasia of 15.66, considerably better than the very best European country, which is Germany.

When we turn to the Cape Colony, we find that the population in 1904 was 2,118,533, and that the growth in the 13 years between census periods, viz., from 1891-1904 was 85.82; an increase to this extent in the 13 years is a very remarkable feature. See Annexure "D." But, in dealing with the Cape Colony figures, it must be remembered that the new element of race is introduced, and therefore all calculations have to be based on the European figures, and quite separately on other races all under one heading, which may be classified as Coloured. I find, in going into the figures, that the Birth Rate in the whole Colony for all races in 1904 was 31.16, and the Death Rate 20.66, showing an excess of 10.50 of Births over Deaths, which compares badly with Australia; but on dissecting these figures and allocating them respectively to the European and the Coloured, the position is considerably altered. I have not been able to get the figures for the whole Colony under such headings, but I have taken the figures applicable to the 34 principal towns as being probably a fair basis, and I find that the average European Birth Rate was 33.61, and the average Coloured Birth Rate 44.86, which clearly proves that the Births in the towns are much higher in proportion than births in the country, as the total of the Rate of the 34 principal towns works out at over 39 per thousand, whereas the actual Birth Rate for the whole Colony was 31.16. On turning to the Death Rates, we find that the average European Death Rate in the 34 principal towns was 14.55, where the Coloured Death Rate was 38.06. Here again we find that the average for all races would be over 26 per thousand, whereas the actual Death Rate for the whole Colony in 1904 was 20.66, thus proving that the Death Rate is also much higher in the towns than in the country.

When we turn to the excess, we find that the average per thousand of European Births over Deaths in the 34 towns is 19.06, considerably higher than any other country which has been considered, while the Coloured excess is only 6.8, which is slightly better than Ireland. One cannot too strongly emphasize these figures. It means that every year 19 Europeans remain alive in addition to every thousand European inhabitants, as compared to 6 to every 1000 Coloured, and when we go back to the increase of the population in the whole Colony for the last 13 years, we find that the European population has increased by 51.19 per cent., while the Coloured have only increased 34.63. It will doubtless be contended with truth that a large amount of this is owing to immigration, but, apart altogether from the question of immigration, simply on the excess of Births over Deaths, on the figures of 1904, the Europeans are increasing twice as quickly as the Coloured people. I have made a calculation, based on the growth between 1891 and 1904, as disclosed by the census figures, and calculating the same increase to be maintained, in less than 100 years the European population will equal the Coloured. This is an exceedingly interesting and notable point, and I may at once state that I was very much surprised in the course of my investigations to discover this fact, because one hears so much of the Coloured danger to the Cape Colony and how quickly the natives are increasing, and how they must inevitably swamp us in the end, whereas there is absolutely no ground for alarm of this kind, as I have already shown the Europeans are increasing very much more rapidly than the Coloured people.

On turning to the Statistical Register for 1903, if the figures given there are accurate, the result is even more astonishing. I give the figures in Annexure "E," and it will be noticed that the average excess of Births over Deaths for the years 1900, 1901, and 1902 was 5,782 European and 2,250 Coloured, showing that the European races in these 3 years at any rate increased nearly 3 times as fast as the Coloured, simply from the excess of Births, without taking immigration into account at all. These figures are so extraordinary that I hesitate to quote them, and I can only state that my authority is the Statistical Register for 1903.

Turning to the question of immigration, I find that in the 5 years ended December 31st, 1903, 75,846 more people arrived by steamer in the Cape Colony than left. How many of these remained in the Cape Colony, and how many went to the Transvaal and the North, it is difficult to say. English figures show that for the same period 151,802 people left Great Britain for South Africa. As pointed out before, the actual increase of Europeans in the 13 years from 1891-1904 was 192,986, and we also notice that in 1904, which there is no reason to believe was not an average year, the excess of Births over Deaths was 19.06 per cent. in the case of Europeans. Supposing that this excess of Birth Rate of 19.06 had been the annual increase from 1891-1904, it would have brought the European population up to, roughly, 480,000, whereas it was actually 570,000. I am therefore of opinion that I am not over-estimating when I

calculate that this Colony benefited by immigration during the 13 years mentioned to the extent of about 90,000, or, roughly, 7,000 per annum. As to whether this will be continued is not a matter within the scope of this paper.

I feel, however, compelled to return to the appalling Coloured Death Rate, which has already been referred to. As pointed out, the Coloured Death Rate in the 34 principal towns of the Colony during 1904 was very nearly 3 times the European Death Rate; and were it not for the still higher Birth Rate every year, our Coloured population would be getting less. I was so much struck with this enormous Death Rate that I thought it would be a matter of interest to find out how it worked out in a place like Cape Town, and I find that during 1904, the year we have been basing most calculations on, the European Death Rate was 14.3, and the Coloured Death Rate 36.2, or, roughly, 2 per cent. less than the average for the 34 towns, but for the 4 years ended 30th June, 1905, it was 37.25. This enormous Coloured Death Rate is due largely to the Deaths of children under one year old. I find that in Cape Town the percentage of Deaths of children under one year among Europeans is 22.70 per cent., and of Coloured 39.39 per cent. The general Death Rate for the whole Cape Colony of children under one year old is 34.92 per cent. Ceylon and British Guiana are both supposed to be very bad climates for children, but in British Guiana the Death Rate is 20.58 per cent., and in Ceylon 25.29 per cent., so that the Cape Colony Death Rate of 34.92 per cent. for children under one year old can only be described as appalling. I do not feel called upon to make deductions from the figures I have compiled to any great extent, though I must confess that it is a very interesting subject, but I may be pardoned in again pointing out the main feature that has been forcibly brought home to me in compiling this paper, and that is that owing to the exceedingly high Death Rate among the Coloured people there is no cause for alarm among Europeans as to the Coloured people becoming a danger through their largely increasing numbers. As to the moral right of tacitly permitting a state of affairs where the Death Rate is utterly unreasonable, that is another matter altogether.

ANNEXURE "D."

POPULATION OF CAPE COLONY.

	European.	Other.	Total.	Increase per cent. European.	Increase per cent. Other.
1691.	922	405	1,325		
1807.	26,720	46,943	73,663		
1865.	181,592	314,789	496,381		
1891.	376,987	1,150,237	1,527,224		
1904. *	569,973	1,548,560	2,118,533	51.19	34.63

* Excluding Territories Annexed since 1891.

ANNEXURE "E."

BIRTHS AND DEATHS OF CAPE COLONY FOR 3 YEARS.

BIRTHS.

	European.	Others.	Total.
1900.	15,380	37,727	53,107
1901.	15,639	38,180	53,819
1902.	15,970	38,140	54,110
Average for 3 years	15,663	38,016	53,679

DEATHS.

	European.	Others.	Total.
1900.	10,193	39,234	49,427
1901.	10,689	34,361	45,050
1902.	8,763	33,702	42,465
Average for 3 years	9,881	35,766	45,647

AVERAGE EXCESS OF BIRTHS OVER DEATHS FOR 3 YEARS.

European.	Others.	Total.
5,782	2,250	8,032

53—BOTANY AS A SCHOOL-SUBJECT IN SOUTH AFRICA.

By S. Schönland, Hon. M.A. Oxon., Ph.D., Professor of Botany, Rhodes University College, and Director of the Albany Museum, Graham's Town.

The attitude of the general public (including the majority of so-called educated people) out here towards the teaching of Botany is very curious, and would be amusing, if it did not concern a matter which I, for one, consider of some importance, both with reference to general education, and even as regards the welfare and prosperity of the country, as I hope to show later on. As a rule, people have an idea that Botany consists in collecting and drying plants, and putting them neatly on sheets of paper, or in counting stamens and such like things; that the greatest Botanists are those who succeed in getting together the biggest collections, and remember the greatest majority of horrible names, that Botany may therefore be made a hobby for people who have not much else to do, and that as a means of training the minds of young people it is valueless. I need scarcely say that these and similar opinions, current in South Africa, and, I believe, also in England, are based on absolute ignorance of the subject. It is very peculiar that such views should be generally current amongst British people, since the British possess the finest botanical establishment in the world, kept up at an enormous cost. I refer, of course, to Kew Gardens, with its Museums, Herbarium Research Laboratory, and Library, and since also the researches of the British Botanists of the present day do not suffer in comparison with the work of the Botanists of any other nation; and, if we go back in the history of Science amongst European nations, we find that ever since the revival of true scientific work, the English Botanists have to a remarkable extent contributed towards the development of their Science, just as in other Sciences the work of Englishmen also can be traced as sign-posts in their development.

A few examples, taken at random, will prove my statement as regards Botany. Shortly after Francis Bacon, about the beginning of the 17th Century, had pointed out that the only true way of studying nature consists in going straight to nature and asking her questions by means of observation and experiments, we find that the Oxford Botanic Garden was established (1632), one of the earliest establishments of its kind. Several of the earlier Professors, notably Morrison and Dillenius, left their mark on the science of Botany. Robert Hooke, who lived from 1635-1703, made considerable improvement in the construction of the compound microscope, and became incidentally the father of Vegetable Anatomy, which, during his lifetime, had a distinguished exponent in the person of Nehemiah Grew. In the 17th century England could also boast of John Ray, who first attempted a natural classification of plants, previous attempts in this direction having been of the crudest. He also made valuable investigations into the nutrition of plants and the movement of sap, and these were followed up by Stephen Hales (1677-1761); but Sachs states, in his History of Botany, published in 1875, that

ANNEXURE "D."

POPULATION OF CAPE COLONY.

	European.	Other.	Total.	Increase per cent. European.	Increase per cent. Other.
1691.	922	405	1,325		
1807.	26,720	46,943	73,663		
1865.	181,592	314,789	496,381		
1891.	376,987	1,150,237	1,527,224		
1904. *	569,973	1,548,560	2,118,533	51.19	34.63

* Excluding Territories Annexed since 1891.

ANNEXURE "E."

BIRTHS AND DEATHS OF CAPE COLONY FOR 3 YEARS.

BIRTHS.

	European.	Others.	Total.
1900.	15,380	37,727	53,107
1901.	15,639	38,180	53,819
1902.	15,970	38,140	54,110
Average for 3 years	15,663	38,016	53,679

DEATHS.

	European.	Others.	Total.
1900.	10,193	39,234	49,427
1901.	10,689	34,361	45,050
1902.	8,763	33,702	42,465
Average for 3 years	9,881	35,766	45,647

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with Hooke and Grew the new light was extinguished in England, one might almost say up to the present day, but this is far too sweeping an assertion. There arose from time to time giants amongst English botanical investigators, such as Robert Brown, Lindley, Knight, and last, but not least, Charles Darwin. However, the first half of the last century saw, especially in Germany, a revival of investigations in Vegetable Anatomy, Physiology, and Morphology, based on developmental studies which, until the last 15 or 20 years, were not in a striking degree forwarded or even shared by English Botanists, and not until the best German text-books had been translated into English, and all coming men of distinction amongst English Botanists had been trained in Germany, did a striking change take place. Naturally, therefore, we could not expect to have English teachers trained to teach Botany properly in schools. It is curious to find that even Charles Darwin's works were more highly appreciated in Germany, and led, generally speaking, to more fruitful results amongst German Botanists than amongst their English colleagues. I cannot go fully into the reasons for this apparent anomaly. Splendid work was done, especially at Kew, during this time by the Hookers, Bentham, Oliver, Baker, and others, but the time of these men was fully occupied by work in Systematic Botany, and, incidentally, by work on the distribution of plants, with the abundant material which was poured in from all parts of the British Empire, South Africa included, but at the centres of learning, little original work was accomplished, and the students were mostly fed with such dry stuff as the external morphology of plants and their systematic arrangement affords. It was not realised that to make the study of plants worthy of a place amongst academical studies, *the teaching of Botany must deal with plants in the first place as living beings*. That under such circumstances the general public looked upon Botany with indifference or even contempt goes without saying. A Science which dealt chiefly with hard names could not command sympathy, and quite rightly, too. It was forgotten that these names are only a means to an end, and I am afraid that this wrong notion has largely survived. All seats of higher teaching in Great Britain are now splendidly equipped both for research and the training of students in Botany, but I am not aware that the teaching of Botany in British schools has made very great progress yet.

It is different in America. From a book called the "Teaching Botanist," published at New York in 1899 by Dr. W. F. Ganong, I gather that in the United States between the advanced college and the lower school work, "botanical teaching is now in a state of wonderfully rapid expansion and transition. Three causes are contributing to this result. First, the natural reaction from its former extreme backwardness; second, a widening recognition of the value of the science, of which Botany is a leading one, in general education; third, its acceptance as an entrance subject by some of the leading colleges." Such a breaking away from old traditions on the part of the Americans, who are always looked upon as so remarkably acute, deserves our most serious attention. American educationalists,

like educationalists of other civilised nations, have recognised that in order to round off education, to sharpen and polish the minds of those who are to be educated, it is not only desirable, but necessary, to include in any scheme of liberal education an inductive science, such as Botany. The true end of education, apart from moral training, is to enable man not only to make the best present use, but to realise the utmost potentialities, of his great weapon by which he rules the universe—his mind. By means of the subjects usually taught—Mathematics and Languages—his deductive faculties are greatly developed, but the other side of his mental power, the inductive faculties, are left undeveloped. With your permission, I will therefore first of all try to show how this great gap in our general educational system can be filled up. Although I do not hold with the current idea that knowledge acquired at school should be of immediate use, I can, however, show that a sound knowledge of Botany is of very great use, especially in a country like ours. I will also try to show that the teaching of Botany might be made to assist the moral training of pupils, and, lastly, I will try to indicate how time for the study of Botany in our schools could be found.

I will not deal with the question whether any other science is equally good for the purpose for which I recommend Botany. Broadly speaking, one Science is as good as another for developing a scientific spirit in boys and girls, but Botany has the advantage that the material for teaching is everywhere available, a kitchen garden being just as useful for teaching its first principles as the richest wild Flora or the well-stocked greenhouses of large botanical establishments. It has, further, the advantage that for its proper understanding, some fundamental principles of other Sciences, such as Chemistry and Physics, have to be mastered, and thus it does not make the pupil too one-sided; at the same time I must admit that other Sciences have advantages peculiar to themselves, and circumstances may make it desirable that these be substituted. On one point, however, I should like to express my disapproval, namely, with regard to the opinion current in this country, that Botany is only suited to girls. Once the great educational value of the teaching of Botany is established, there is no reason why boys, as in German schools, should not learn it also.

Botany, I maintain, is an excellent subject for making the mind active and alert by developing the scientific instinct in boys and girls. "Of all scientific instincts," Dr. Ganong truly remarks in the book already quoted, "the very foremost is that for exact observation. No others can be of much value if it be lacking." Now, whatever branch of Botany we take up, whether Morphology, which concerns itself with the forms, origin, and relationship of the parts of a plant, or Anatomy, which deals with the internal structure of plants, or Physiology, which deals with the functions their organs perform, or Systematic Botany, which classifies plants—observation, strict observation, and accurate observation is a *sine qua non*. The material for observation has, however, to be carefully selected by the

skilled and trained teacher, otherwise the mass of facts that may be observed would be simply confusing. But take a few common seeds to begin with. We can "notice their sizes and shapes, the exact kinds and relative portions of all of the markings on the coats, and their relation to the parts of the embryo inside, the number of the coats, the full number of parts in the embryo, and the exact way they are put together; all afford, under the skilled teacher, fine materials for practice in observation." "Later the seeds may be germinated, and the exact place and mode of new structures, the position of newer leaves relatively to the older," the development of the root, and many other features may be noticed and compared in different plants. We can at once also vary the conditions under which these seeds are germinated. We can trace the influence of heat, light, air, moisture and gravitation. We can grow them at various temperatures, and show that seeds will just germinate at a certain minimum of heat, they will not germinate beyond a certain maximum, they will germinate best at a certain optimum. We can then discuss the question of the conditions under which seeds will keep this vitality. These hints will show that Botany gives abundant scope for accurate observation. This will scarcely be disputed, but I wanted further to show that, at all events for elementary work, a good deal of this can be done with material which is everywhere available, a few dozen seeds of common garden or farm plants being quite sufficient to keep a class usefully employed for many hours. In a similar manner one can go through a whole course of teaching Botany at schools without in many cases having to search for material for study; besides, very few tools are required for it.

To make observations accurate, we should at every stage make the students draw the objects they see, and this is a point which all skilled teachers insist upon.

"Next among scientific instincts comes faith in causality, involving the belief that every phenomenon is yoked with preceding factors, combined with a desire to learn what these are." In practice, the observation of facts and the enquiry how they are caused, should never be separated, "and the cultivation of the habit of testing the connection of causes and effects by experiments is, therefore, a most important part of botanical training." Here, again, Botany offers facilities which no other science possesses. The dullest child, when observing germinating seeds, will be struck with the fact that the root always grows perpendicularly downwards, and the stem perpendicularly upwards. The every-day, dull mind will not bother further about this fact. It was so when his father germinated seeds, and will always be so. The intelligent man with true scientific instinct will, however, want to know the cause of it. I may at once say that the ultimate cause is not clearly discovered yet, but the immediate cause for making root and shoot grow in opposite directions is the attraction of the earth, gravitation. This was discovered by an Englishman, Andrew Knight. That he was right can easily be shown to a class of students, first, by placing germinating seeds on a perpendicular, slowly-revolving wheel, when the attraction of

the earth will be annulled and roots and shoots will grow in all directions, or, secondly, by placing them on a rapidly-revolving wheel, when the centrifugal force will take the place of gravitation, and the roots will grow outwards, and the shoots towards the centre. Again, the fact that seeds require air for their germination can, by a few simple experiments, be shown, and it can further be easily demonstrated that we have here a process going on which is very similar to the respiration in animals and man himself.

You can very easily see that in Botany of this description there is very little use for counting of stamens, or long names for shapes of leaves, or unpronounceable names for the plants themselves. Still, Botany must give the pupil a picture of the whole science, and the study of systematic Botany has also a great value. It should, in the first place, stimulate exact observation, and, when based on careful study of Morphology, it will give even the elementary student a remarkable instance of order in an apparently complex whole, and its study should further help the pupil, on the basis of exact dates, to acquire a power of terse, logical, complete expression.

Systematic Botany further brings us into touch with the native Flora in the country, and I ask you: Is it right that we call ourselves civilised, and let our children grow up without the slightest knowledge of the things that are commonest around us? Is it right that our children should not even get an intelligent glimpse of the richest Flora in the world with which they are surrounded? If, as is generally the case out here, all pure knowledge is despised, and this state of things continues, there is one thing quite certain, that the hordes of savages over whom we are supposed to rule will raise themselves to the intellectual level of the white population, and there can only be one result, and that is—there will be no room for a white population in South Africa. If it is quite certain that European nations owe their present superiority over other nations to a large extent to their study of subjects which do not immediately pay, we cannot afford to break away from a course that has so admirably succeeded in Europe. We hear so much about the progress of Japan, but it is a significant fact that the Japanese have paid just as much attention during recent years to pure Science as to applied Science. I may mention, in passing, that the most important fact discovered during recent years in Botany, was found and rightly interpreted by a Japanese Botanist.

Of course, in studying Systematic Botany, even in elementary courses, we should always remember that we are dealing with living beings. We must know "how plants live, why they have their shapes and colours, how each one fits so exactly its individual surroundings." This, in the hands of a trained teacher, and in a country like ours, gives endless possibilities for interesting pupils in their work, and the grouping of plants in a system of classification is, after this, not a mechanical piece of work done with great exertion by bored pupils, but is simply the orderly arrangement of facts with which the pupils are more or less familiar.

I will illustrate the meaning of these remarks by a very simple example. Take the flowers and fruits of an Aloe. From the text-book hitherto prescribed we learn "that the perianth is sub-cylindrical, straight, or curved, the segments more or less connate, three inner narrower and thinner than the outer ones. Stamens hypogynous, mostly included in the tube. Ovary sessile, with numerous ovules. Fruit, a three-celled capsule, opening loculicidally. Shrubby or aborescent, succulent plants, with bitter juice," etc. Now, this may be very interesting to some people, but must be an awful bore to a child.

The skilful teacher would have most of these facts already brought out before he comes to Systematic Botany. I will only mention a few of them. He will have referred to the shrubby or arborescent growth of many Aloes when speaking of shrubs and trees generally. The succulent character of these plants will be dealt with when speaking of adaptations of plants to dry climates. The bitter juice will be mentioned as one of the protective characters of plants. The forms and arrangement of the leaves form striking examples when dealing with this part of the subject. The flowers and fruits are, however, a regular godsend to the South African teacher.

The colour of the flowers is bright, and copious nectar is secreted by them. At once we jump to the conclusion that we have here an instance of a plant which is cross-pollinated by insects or birds. Let us look, therefore, whether this is the case. We find, without difficulty, that both sugar-birds and bees visit the flowers. In drawing flowers of different ages, we notice that those which have just opened only exhibit their stamens. These stamens discharge their pollen and then wither (in some species they are withdrawn altogether). About this time the style elongates and occupies eventually the same place which the pollen-bearing receptacles, the anthers, previously occupied. In other words, although the flower has both male and female organs, it is at first in a male state, and passes afterwards into the female state. The pollen of the flower can, under ordinary circumstances, never reach the stigma of the same flower. Some extraneous agency, birds or insects, is required to effect pollination. The teacher can now show the origin of the nectar, the position of the ovules. The floral diagram and the floral formula can be constructed. When this is done we have pretty well all the facts which I have quoted above, but the dry bones are now clothed with flesh.

But we have not done with the Aloe yet. The seeds afford an excellent illustration of a type of plant which is easily spread by the wind. They are exceedingly light, and present a large surface to the wind when discharged. Now, we must have noticed that the flowers are all pendulous. If the seed vessels, which open at the top, were also hanging down, the elaborate arrangements in the seeds to be spread about by the wind would be quite useless; they would probably all drop to the ground when there is no wind to

catch them. We notice, however, that when the flowers are pollinated and begin to wither, the flower-stalk straightens out, and all the seed vessels stand in an upright position. The seeds now, instead of dropping out by themselves, cannot get out at all, unless the seed vessels are violently shaken by the wind; in other words, when a seed becomes free there is the wind to carry it along. Now, our Flora abounds with similar adaptations to external agencies, and once shown to intelligent children, there is no difficulty in interesting them in the different kinds of seed vessels and the mode they open. They will then perhaps even remember what a "loculicidal capsule" is.

The study of Botany in this country should have a special attraction, because it gives boundless enjoyment to its votaries, and is especially calculated to relieve the dullness of life on isolated farms; but it does more, it gives everybody who has even an elementary knowledge of it a chance of contributing to the development of the Science. Of course, there are, in the first place, numerous undescribed species to be discovered; but we know very little yet about the exact distribution of even our common plants, and everybody can assist in filling up that gap, and if we come to the Ecology of plants, their adaptations to their surroundings, everybody who has the requisite training and leisure can make a name for himself or herself by studying our native plants in that respect. It is an almost untrodden field, in which a rich harvest awaits the honest worker. There is a chance here especially for our teachers, because we can scarcely expect the ordinary pupil to carry on original investigations.

In all Sciences, the most far-reaching discoveries, from a practical point of view, have, generally speaking, been obtained as by-products of studies in pure Science. I need only remind you of the history of the Science of Electricity or to the history of the development of the coal-tar industry, or, to take an example from more recent times, the Röntgen rays were not discovered by a man who intended to place a most powerful aid into the hands of our surgeons, and yet he actually did so. But the point I would bring out is this, that their discovery has been quietly brought about, simply with a view of extending our knowledge. The results which made them famous were simply by-products of the main work. In a similar manner, many important advances in the practical application of a knowledge of Botany have been made by men quietly pursuing their studies from a purely theoretical point of view. Thus, the practical application and the development of Bacteriology had only become possible when a German Botanist, Prof. Cohn, had quietly studied Bacteria, and classified them from a purely morphological point of view, and when one of his pupils, the now well-known Prof. Koch, had devised methods to separate these very minute organisms and to grow them separately. Bacteriology can, therefore, be claimed to a large extent as a branch of applied Botany. In health and in sickness Bacteriology concerns everybody more than is usually believed, and a rudimentary knowledge of this Science, which, after

all, means nothing else but a rudimentary knowledge of the laws governing the lives of a multitude of primitive vegetable organisms, should be of the highest value to everybody, and should not be withheld from our youths. Closely connected with the knowledge of Bacteriology, in the restricted sense, is a knowledge of fermentative processes generally. This, again is a matter which deserves our attention, and there are no difficulties in imparting to boys and girls just enough knowledge of fermentation to make them realise the processes which go on in making of bread, cheese, wine, beer, and many other articles of common use, and make them also understand the processes by which fermentation can be avoided if not desired, and, mind all this this can be done by teaching the principles of Botany.

Botany is, as you know, in a way the handmaid of Medicine, and other useful applications of it could be mentioned, but I will only refer to one in particular—Agriculture, in the widest sense of the term, including Horticulture and Forestry. Agriculture is nothing but applied Botany, and success in Agriculture means in most cases the successful application of botanical principles to special cases. Now, the majority of the pupils of our schools, whether male or female, return to farms where Agriculture is of the utmost importance. Let me show by a few examples only (which, however, could be multiplied to a considerable extent) how a knowledge of Botany could be of direct use to them. Every student of Botany learns that ordinary green plants require certain inorganic materials if they are to grow at all. In manuring ground we supply deficiencies which either were there originally, or were caused by taking away crops. Knowing this, we should get our soils analysed to find out their deficiencies in order to make them good in a rational and economical manner. Yet many of our farmers go on year after year by rule of thumb, if they do manure, or they do not manure at all, because their fathers and grandfathers did not do so on the same plot of ground, quite forgetting that if there was a sufficient amount of the necessary materials for plant growth 20 or even 50 years ago, there is no guarantee that sufficient is left for the crops at the present time. A little knowledge of these matters would frequently turn a trifling expense into a big profit. Then there is the rotation of crops, so largely practised in Europe, to which our farmers would take more readily, to their great advantage, if they knew the principles which led to its adoption in other countries. Another important matter is the selection of seeds for sowing. One would think that every rational man would only sow the best seed and only pure seed, and yet it is a common practice in this country to reserve the tailings, the unsaleable seeds, for sowing. Thus seeds of crops, the vitality of which is impaired, are used for sowing, and mixed with them are countless numbers of seeds of weeds. No wonder a farmer once said at a public meeting at Alexandria, "that farming was going to the dogs, for when he sowed wheat it turned into drabok" (a most objectionable grass). He was quite unconscious of the fact that he sowed year after year vast quantities of seeds of drabok, which

somewhat resemble bad seed-wheat. I explained matters to him, and asked him whether he had ever observed drabok turn into wheat. He replied that he would not say that it could not turn into it. Then there are our plant diseases, which are getting worse and worse every year, and which should be understood by the average farmer. Then there is the deterioration of the veldt, which concerns chiefly our stock farmers. Everyone knows that stock eats only certain kinds of plant growing in the veldt. This simply means that, unless precautions are taken, the useless kinds get a better chance of propagating themselves than their useful competitors, and may even dominate the veldt, to the complete, or nearly complete, exclusion of the useful ones. The natural course to adopt, and a course which is adopted by thoughtful farmers, is to give portions of the veldt an occasional rest, to let useful grasses seed occasionally to give them a chance to regain their hold against the weeds. This is commonsense, but it is a deplorable fact that, broadly speaking, the prevailing system of education does not develop commonsense. Huxley has rightly said that Science is systematised commonsense, and yet we exclude it from the education of our children, either by shutting it out altogether or teaching it, as is done usually with Botany, in a worthless manner.

What, now, is the moral influence that may be expected from the study of Botany? No one can be brought into constant touch with the beauties and the laws of the organic world without being the better for it. It raises him above the sordid actualities of every-day life, it occupies his mind when out for a walk, it gives him an intellectual companion in whatever part of the globe he may be placed, and, if it is true that bad thoughts and bad deeds are the outcome of idleness, the man or women who can fill up his or her spare moments with a study of Botany has a great deal of the temptation removed which empty minds encounter. But I maintain that Botany does more. It tends to make its students humble, truthful, and straightforward. It makes them humble, because the more it is studied the more one sees how little we know, and how the inward nature of things must be for ever be hidden from us. We talk about protoplasm as the bearer of life, we know approximately its chemical constitution and its reactions, but we shall never know *why* it is the bearer of life, we shall, e.g., never know why a tiny speck in the seed of a bluegum brought from Australia develops into just such a giant tree of a particular kind as it would in its native home, while another speck develops into a plant of quite a different kind. Hundreds and thousands of similar enigmata cross the path of the thinking student of Botany. They may make him an agnostic, a man who frankly confesses that the fundamental principles of the organic, and, for the matter of that, also of the inorganic world are totally hidden from us, but they will also make him humble and reverent, acknowledging the shortcomings of the human mind and of human powers. I said, further, that the study of Botany makes one truthful and straightforward, as would also the study of any other Science, because such a study is a continuous

exercise in trying to find out the truth about the subjects of study, in stating the results of one's finding in plain language and drawing matter-of-fact conclusions.

I am aware that a number of schools in South Africa have admitted the study of Botany to their curriculum, and I may perhaps be allowed to acknowledge the encouragement which it has received at the hands of the Superintendent-General of Education of Cape Colony, Dr. Muir, F.R.G. Let us hope, now that there are in several places in South Africa higher institutions where teachers can be properly trained in the higher branches of this Science, a better state of things will soon be introduced, and that every school which does not take up some other Science will get teachers who can teach Botany in a proper manner. The question then remains, how is the time to be found for it? Already there is a cry that there are too many subjects taught. Well, if you agree with me as to the claims of Botany, you will also go so far that some other subject ought to suffer. Fortunately, there is one subject which, if fortune favours, can afford to be lopped of some of its branches—I refer to Arithmetic. I have been informed on very good authority that if we had a rational system of weights and measures, an enormous amount of time could be saved in the teaching of Arithmetic. If, instead of our present awkward troy weights, apothecaries weights and others, we had all round a decimal-metrical system, like most other civilised nations, much of the unnecessary work of schoolboys and schoolgirls could be saved, and time found for more intellectual pursuits. There is a movement on foot to urge upon Parliament the introduction of the metrical system, and I can assure you from actual experience that within a very short time after its introduction everybody would rejoice over it. However, the argument which I have brought forward will, I am afraid, have little weight with our legislature. Let us hope that others will prevail, and that our schools will thus be relieved of a burden which they needlessly bear, and the removal of which will afford them time to give attention to Science, and especially to the study of Botany, on which, I trust, you will look with greater sympathy than is usually accorded it.

A question which was only put to me a couple of days ago by the principal of a school remains yet to be answered. It comes to this: Suppose we want to introduce Botany as one of our objects and have a trained teacher, how are we to get the material for teaching? I have already said that a kitchen garden affords a great deal of material, but, of course, other aids are required. In the first place, a certain amount of apparatus is required to teach the principles of Physiology.

If you glance through one of the elementary text-books of Experimental Plant-Physiology, such as McDougal's translation of Oels' book, you will see that even the poorest school, with the aid of the Education Department, could afford to get a suitable set of apparatus. A few pounds will cover the cost.

In the teaching of Anatomy a miscroscope, costing about £10, will be required. Very good botanical slides can now be bought in

England for about 9d. each, so that if £25 were spent on the outfit for the teaching of Anatomy and Physiology, it could be carried on as far as school-children can be supposed to know it. In the teaching of Morphology no apparatus is really required. Still, to facilitate matters, a few models may be acquired to help to demonstrate the structure of small flowers, such as the flowers of Grasses.

One great difficulty teachers have to contend with is the naming of the native plants. Now, as there are at least 12,000 species of flowering plants alone in South Africa, it is manifestly impossible for an ordinary teacher to name the plants in the neighbourhood of the school, but this difficulty is more apparent than real, as we are always glad to name plants for teachers at the Albany Museum, provided reasonable care has been taken in selecting and transmitting the specimens, which can be sent to me free by post and rail; besides, similar facilities are available in Cape Town. Every teacher should then, with numbered specimens kept back, form a small local Herbarium for reference; the formation of a collection of fruits and seeds is also very desirable, and I think in many cases the teacher might go a step further and plant some of the native plants round about the school-building. It is wonderful how much help one gets from such a collection of live plants, even if it consists of only a few dozen species. There are also some places, like Kimberley, where it is very difficult to get any wild specimens for class-teaching. Here the formation of a small botanical garden is imperative, and a type herbarium and a collection of fruits and seeds should be acquired by purchase or exchange.

54—CLIMATIC INFLUENCE UPON CHARACTER.

By J. Abercromby Alexander.

[Paper not Printed.]

55—THE PLACE OF MANUAL TRAINING IN SOUTH AFRICAN EDUCATION.

By Thomas Lowden.

Among the many questions before the public of South Africa, not the least important is that of Education. Recently I was glad to notice, that the *Rand Daily Mail* had, in a series of leaders, directed attention to the question of practical education, under the title of "Our Future Artisans."

In the Colonies it is just as much of vital importance, and perhaps more so, that our youths should be as properly prepared, if inclined to take up trades, as the Home youths. It seems to me that South African born and reared youths, and over-sea born, but reared here, should take the bulk of positions as highly-skilled and highly-paid artisans and mechanics, and high places in offices or the Civil Service, and not have to take, as is too often the case, what is left after valuable posts have been filled by highly-paid imported men. Undoubtedly good colonists are needed, but not at the future expense of our boys. Further, in a country like this, where the mineral wealth has only been scratched, where agriculture is practically only emerging from its infancy, and where manufactures are yet to be born, the education must be such that the youths, our future pioneers, the kings of isolated places, may be self-reliant and self-contained. That our boys have been, and are, still somewhat handicapped, most will agree with me, and that being so, it is necessary to study the cause and the means of prevention. On enquiring why so many imported men from all parts of the world occupy the good positions, we are told the lack of training facilities for our Colonial youths has kept them in the second place. When should we begin the training of "Our Future Artisans," Argiculturists, etc.? Undoubtedly the training should begin the moment a child starts its school life, and should be of such a character that the transfer from the classroom to the business life should simply be a change of environment, and a change of master. That business life is simply an expanding of school life, and the application of the principles, information, moral tone, perception and application, reliability, and habit of work acquired at school, and that there is nothing to unlearn.

Educationalists must face this question. Perhaps no profession outside those of religion, law, and medicine, sticks tighter to Tradition, or is more classic and conservative than the Teaching Profession. Because, in the Middle Ages, what little information was to be obtained, what little was known of Theology, Philosophy, Science, and Mathematics, was wrapped up in books written in Latin and Greek, and it was necessary for scholars to get at that information first hand, to be expert in Latin and Greek, is no good reason why so much of our students' time should be spent over dead languages. Nor are any of the arguments put forward by those in favour of classic education of commonsense or utilitarian value. The needs of the community are sacrificed to custom. Ninety per cent. of our students will never require Latin and Greek in their manhood.

Save for religion, law, literature, and medicine, as in the old days, only the students destined for those vocations should be compelled to take the classic side. That our boys think for themselves in this matter, is shewn by a question put to me by a youth during a machine-construction drawing lesson. He is attached to one of our colleges, and his inclination, supported by his father, is towards the Engineering Profession. Evidently he was turning over the utilitarian value of his different studies, when he asked: "What is the use of Latin to me?" The only practical answer I could give to suit him was, "That it will help you to pass your School Higher." In the course of the lesson attention had been drawn to the connection between Physics and Engineering. The boy saw the advantage of the time, as far as he was concerned, spent in studying physics, and the disadvantage or waste of time spent on subjects not bearing on his profession. Perhaps it is not so much "system" or code that is at fault, for, after all, it is the teacher that makes codes and systems successful. If our teachers could and would show the relation between school-work and business, there would be fewer complaints about idle, inattentive children. Nor should we overlook the too often stultifying actions of Inspectors, who from their lofty pinnacle, have the opportunity of taking a broad survey of education, and so should be able to advise teachers what is best educationally for the district, yet by their methods of Inspection, make a dull system of education duller. One can hardly credit 20th century Inspectors caring only for the 3 R's. Yet that is too often so. Had the fourth R—Drawing—been included, it would not seem so bad. This anxiety over the 3 R's, and the cramming system to get a glib facility in them, too often give rise to a distaste for those subjects, with a result that the pupil, once freed from school control, throws studies to the winds, gives up reading, and is extremely loth to put pen to paper. It is lamentable to note the poor attendance at the various evening classes. Further, how few read books in our libraries outside the fiction class, and it is surprising to find that the bulk of those who go in for improving literature are of foreign extraction and education.

After the war, in the Transvaal Colony, there was a great opportunity of giving to that country an educational system equal to, or superior to, anything in the world, because there was the past and present experience of the world's systems to profit by. Yet we find custom and tradition too strongly adhered to, and old methods are perpetuated. Theory without practice is still the order of the day.

If there be one subject more than another which needs stripping of sentiment and the pandering to faddists, it is the subject of Drawing.

Nowadays there seems to be a tendency to attempt to teach Art before the Alphabet of Art, namely, Drawing, is mastered, and little or no attempt is made to fit it into a child's school's life. Scale Drawing and Geometrical Drawing are elbowed out by Brushwork and Brushwork design. This latter class of work is undoubtedly

recreative and somewhat pretty, and would no doubt be admirable in a Pottery District, but, alas! decorative china manufacture is not one of our productive works. I might even go so far as to say that class of drawing is suitable for a private school for young ladies, where the veneer of a so-called finish is more highly thought of than a sound education. Meanwhile, in our primary schools, where it is run for show purposes, the practical drawing is neglected. As ninety per cent. of our pupils will have to be workers—keen, alert, self-reliant, ready with pen and pencil, something more is needed than to make them dreamers of the beauty of flowers, or of the delightful shades of a butterfly's wing. Although I doubt, with the crude shades of colours used for brush and crayon work, they might be distorted dreams. Let us first teach in our primary schools Drawing as the Alphabet of Art. Anyone who tried to teach Reading before the Alphabet was mastered would be looked upon as a lunatic and a crank. Some people are to be found who look upon artists as cranks. Be that as it may, the so-called Drawing in the lower standards is no preparation for higher Manual Training in the upper standards, or the practical needs of after-school life. At present the application of brushwork is limited to the washing in of maps, or the colouring of an architectural drawing, or the washing in of a mechanical drawing in an engineer's office, to show different materials. Adults need facility in using a firm point, such as a pen or pencil, in sketching. If they want to illustrate an idea, or give an outline for construction, the brush is the last thing anyone would think of using.

I was much struck with the sketching powers of the pupils of a certain school. Sketching was encouraged in every way possible. For instance, in an arithmetic lesson, where the sharper pupils would be finished the set work before the slower ones, so that there should be no idling on the part of the sharp ones, the quicker ones were allowed to practise sketching on spare paper provided. This was turned to account in the essay and composition tasks of the upper standards, by the pupils being required to illustrate by pen or pencil sketches, the written matter. The results of that happy combination were delightfully good.

Manual Training takes into consideration the co-ordination and correlation of drawing and dexterity by various occupations. To secure a proper gradation, Drawing, combined with manual exercises, should be compulsory in every class of primary and secondary schools.

One of the greatest reasons for advocating compulsory Manual Training is that the great dividing line between civilised and uncivilised man is the use of tools—the axe, saw, plane, hammer, square, chisel and file; and the modern machine shop is but an aggregation of these tools driven by steam. T. Carlyle wrote: "Man without tools is nothing, with tools he is all." Doubtless the old style of education produced men of learning, but the new style of education—"Learning by Doing"—will produce men of action and resource, because

not so much time has been spent in acquiring knowledge of the past, but rather more has been spent in teaching pupils to use knowledge acquired in producing fresh knowledge in the future. I believe the book "Robinson Crusoe" owes its popularity in that it treats so much of tools and work.

The early education of young children in primary and preparatory grades of secondary schools and in private schools commences on good lines—the kindergarten, that of action, seeing and doing. But, unfortunately, in too many cases this good start is not followed up, till perhaps the pupil reaches the upper classes, when a "feeble dash" is made to make up, by giving the boys a course of woodwork. If the pupil is to receive an all-round development, the manual occupations of the kindergarten must be continued in some form or other to the highest standard. There must be no break. Of the many names used for this form of education, "Applied Drawing" seems quite the most sensible.

Many years ago in Liverpool, when educationalists were beginning to consider the experiments of teachers in Sweden, Finland, Russia, Germany, and the United States, it was decided to try Woodwork for boys, and so as not to offend the susceptibilities of Trades Unionists, it was decided to call the subject "Applied Drawing." There is more in that title than appears at first sight; and if the various branches of the subject are taught in that spirit as well as in the letter, there will be no doubt as to the success of the training. The application of Drawing—the Alphabet of Art—taught in this way is a valuable form of expression, expressing the results of sight and observation, and by so doing is a means of culture. Ruskin says: "I am nearly convinced that when we see keenly enough, there is very little difficulty in expressing what we see." Artisans and mechanics, with the allied professions, need Mechanical Drawing and Free Sketching. The question arises how can this be obtained along with manual dexterity. Courses of cardboard work and modelling in plastic material have been arranged for the first three or four standards. Beginning with Standard I. by drawing to measurement on cardboard with rule, set-square, and compasses the simpler geometrical figures, and proceeding gradually to making nets for trays, boxes, and geometrical solids, the construction drawings for more complicated models, such as a photo frame, as the child moves to higher standards, facility in the use of drawing tools and a readiness and accuracy of measurement is acquired. Dexterity and love of work is obtained by cutting out these working drawings, binding and fixing them as the model requires. Freehand is cultivated by drawing plans for geometrical tiles. On the plan drawn the tile is built up bit by bit in plastic material—clay or plasticine. The smoothing off of the surface, the cutting and trimming of the edges to shape and size, add to the dexterity of the pupil. On these tiles and similar ones, sketched outlines of leaves, flowers, etc., may be made from nature, and afterwards models in relief of the subject. Teachers can easily demonstrate on rough

paper, pinned on the blackboard, conventional relief of various leaf, flower, and fruit forms. Once the pupils grasp the principles, they may be given the opportunity of original modelling. This links modelling on to nature-study, and does away with the old-time system of drawing from cards, which were more often than not inartistic. After having briefly sketched a general idea of Manual Training Modelling, may I just briefly sketch out how in two or three short lessons a beginner may be taught several geometrical facts concretely? The first cardboard exercise in Standard I. will most likely be to cut out a square and bind it. The corresponding exercise in Modelling will be to make a square tile. A convenient size would be a 4in. square. This would be drawn freehand and tested by rule. On completing the square by cutting along a diagonal, we would get two triangles, similar to a 45° set-square. Placing the triangles together again, the pupil could demonstrate for himself that a square figure 4in. x 4in. contains sixteen square inches. Now, if the tile has been made ½in. in thickness, by cutting it into four squares of 2in. sides, and placing these one upon another a 2in. cube is formed. By cutting off the four corners of the cube an octagonal prism is obtained. Further trimming of the corners and afterwards smoothing with the fingers brings a cylinder. The pupil would probably contrast this method with the way he made a cylinder in the Kindergarten by rolling the plastic material between his hands, or between his hand and the desk. Later in his school life, when in the woodwork room, he makes a round ruler out of a piece of wood, by first making it square in section, next octagonal, and finally planing it round, he will think of his early modelling in plasticine. Let a child model a hexagonal nut, how he will notice the nuts on bicycles, wagons, and machinery. An intelligent and sympathetic observation has been aroused in the child for practical outside things. Working in this way through the first 3 or 4 standards, combining freehand and mechanical drawing with cardboard work and modelling, a pupil will have acquired sufficient dexterity in the use of instruments of precision in drawing, a knowledge of measurement and its application, a freedom of sketching, and a love of work for work's sake that will enable him to obtain the full advantage of wood and metal work courses. Woodwork courses, with the corresponding set of working drawings, followed by, as circumstances permit, examples in metal work, complete the "Hand and Eye" side of school life, and I am sure you will agree with me that a youth who, before leaving school, can execute models such as these, and turn out similar drawings, is fairly well equipped for the battle of life, and has a fair chance of giving satisfaction to an employer. Too many people think Manual Training an extra, a thing apart from the ordinary school life, whereas, if it be worked on proper lines, it makes school life real and earnest by linking up the Theoretical with the Practical. Nature study should teach enough Botany to enable pupils to understand the growth and formation of timber. Arithmetic should teach enough mensuration which could be applied in the woodwork. The

commonsense geometry and the handling of instruments taught in the various branches of Manual Training will soon prove that everyone can be taught to draw. Drawing is as easy to teach as writing. We are nearing the day when Professor Huxley's remark will be fulfilled: "That to every well-equipped school a Laboratory should be attached, and to each Laboratory a workshop." Great interest is added to the science studies when the pupils are able to make scientific apparatus to illustrate their work. May I, in conclusion, while thanking you for your courteous attention, solicit your earnest interest for, and your best efforts towards, the extension of practical education, remembering that

> "When eye and hand you deftly train,
> Firm grows the will and keen the brain."

So that in course of time all over this sub-continent our schools will be turning out as well equipped products as the schools of Europe or America.

56 -LIBRARIES FOR SCANTILY POPULATED DISTRICTS.

By B. L. Dyer.

Some few weeks ago it was suggested to me by the President of this section that it would be of interest to this meeting if I would say something about the desirability and the practicability of keeping the teachers on farm schools in touch with the libraries of this country.

Life in the larger centres of population has certain advantages, and your educationist has found it within the region of practical politics to make education compulsory in such centres. But when he comes to deal with the people dwelling in the scantily populated districts he finds much more difficulty in making education compulsory—and he has to adopt the expedients of farm schools. In these schools he wishes to have an educated man or woman in charge—and he sees the difficulty of expecting men and women to keep in touch with education, or to keep up to the desired level of culture if they are out of touch with books and libraries.

But this is a part of a larger question—for how can one expect to settle an educated population in the areas which will only support a limited population if they are out of touch with books?

Educationists recognise the right of the children on widely separated farms to a participation in the state provision of education, and I would advance a plea that the people resident on these farms are as actually entitled to a share in the library provision of this country as are their children to a share in its educational provision. The model community is one that has community of ideal, of interest and purpose—" likeminded persons who know and enjoy their likemindedness and are therefore able to work together for common ends."

We have a partially state-aided voluntary system of libraries in this country, and I would enter a plea that the farmer who desires books to read is as much entitled to the use of the public library as the town dweller, and that the library system of this country will not be satisfactory so long as the residents in the scantily peopled districts, whether farmers, teachers, or miners, are entirely out of touch with it.

If the communal or public library is necessary in the town, how much the more necessary is it to the scantily peopled district where people have less opportunity for exchange of thought. The state aids the library by grants on the pound for pound principle, and wherever it has been found possible to establish libraries the groups of people who are in touch with them have been so assisted. But if an educated man is dropped down into a district without a library, the whole system of state aid breaks down, and he can only borrow books from the nearest library at a cost of 8d. per pound on the journey to and from the library—unless he lives near a railway line, when the railway authorities very kindly carry his books to and from the library at single rates for the double journey!

his school years, it were the height of folly not to keep him so accustomed. Give him the chance never to leave his education behind, and how much of influence for good may the libraries of this country be?

I have dwelt but little on the practical side of the question—of how money is to be found for the extension of library privileges and facilities to the scanty populations—but your educational authorities have shewn how elementary educational facilities are to be extended—and I doubt not that once the library is recognised as one of the true educational factors of a community, that the state will see its way clear to do its duty.

establish libraries it determined that town and county alike should benefit. In each of the county's twenty-six polling districts it was decided to establish some sort of book depôt, so that every man who wished it could borrow books. The library board caused travelling book boxes to be made, and little travelling libraries were sent out to wherever they were asked for—and in the post office, the school, or the store—wherever people needed them was set up a library of frequently changed books. The cost of transport of these boxes was made a general charge against library income, and the people in the most remote polling district had their books at the same cost as the people in the county town. Twenty-three districts were supplied the first year—and in the fourth year no less than 66 depôts for books had been set up—whilst Boonsboro' and Williamsport, places of 800 and 1,000 inhabitants, had so grown to use their little libraries that news-rooms have been fitted up, and libraries of two and three hundred volumes, of which some 40 are changed monthly from the central depôt, are in good use here.

Thirty-three of these book depôts are along the lines of railway communication and are easily served, but no less than 30 are away from it, and for these a travelling book wagon has been established, which "drives up to the farm-house doors, through the county lanes," gathering up the books that have been read, and replacing them with those that have been asked for. With a total population of 45,000 souls, it is interesting to note that in 1905 the library issued some 50,000 books to the town readers, and nearly half as many to the residents in scantily populated districts.

This is not a solitary instance of the good work that America is doing, but it must be remembered that the system of libraries is not a voluntary state-aided one, but a compulsory rate or tax supported one—as in Australia where the system of travelling book boxes has been brought to a most perfect one, and here the state in addition to making a fixed grant for library work carries all library books to and from the libraries entirely without charge. In at least one West Indian Island a similar system and concession has worked well.

In South Africa little has yet been done in the way of travelling boxes, because the costs of transit have hitherto been heavy. A few subscribers resident along the railway lines have had out parcels of books—but nothing systematic has been done, except perhaps at Maritzbuhg, and at the Victoria Memorial Library, Salisbury, Rhodesia. At the latter place a special feature is made of the lending of agricultural books to farmers.

By private effort a system of travelling libraries was instituted, for an account of which I am indebted to Miss Neuman-Thomas. And this was the Markham Libraries presented by Miss Violet Markham and tne Victoria League. These consist of eleven boxes of books, each containing a well selected library on such topics as "India," "Canada," "Italy and Greece," etc., and they were intended to travel more especially among the women of this country.

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find the close relationship which is growing up at Home between the Public Libraries and this Union. Almost invariaoıy where the suggested courses and readings have been adopted, there has been an increased interest in the non-fictional contents of libraries, and "a general levelling-up and encouraging advance would almost certainly follow if the members of the Union in a district would take an earnest and practical interest in the management and improvement of libraries."

In South Africa the work of this Union has been much helped by the Guild of Loyal Women, and I know of no nobler work for a band of ladies than the taking under their charge of the improvement of our libraries, and the extension of their work In small villages and in places where people otherwise would not have the energy to establish reading circles or clubs, through the efforts of the Guild branches of the Union have been formed and good work is being done—in Namaqualand there is a circle, while in Griqualand East a band of young farmérs meet regularly under the leadership of a farm teacher to read. In the Orange River Colony, with the kind assistance of the S.A. Constabulary, it has been found possible to stimplate interest in books and reading in "remote districts"; at Libode and at Umtata good work is being done—and the people in the scantily populated districts are being awakened to the use of books and the value of the Union.

And now in conclusion of what is a discursive paper—may I once more point to the case of the schools, and ask if the example of their passing from the voluntary to the compulsory may not afford us a solution of the library problem. In the schools of the future we are told that the state will provide compulsory elementary education for every child free of charge—out that all higher education shall be still voluntary. Can we not mould our libraries in the same plan, use our state aid for the establishment and upkeep of libraries easily accessible to all, whether in town or country, consisting of the great works of the world, and can we not leave to a super-added voluntary system the provision of that lighter and more recreative reading that is after all more of a luxury than a necessity?

I have tried to plead the case of the educated man in the hinterland to a share in the benefits of a possibly improved library system, and I would ask you to remember that if he does not get this share you will only reproduce in this country the problems of the older lands—where the first result of a compulsory education that came into being without the provision of any attractions for the educated man in the country was to attract the people from the country to congest in the cities, and where every effort is now concentrated in the cry "Back to the Land."

Even in this comparatively new country the travellers have over and over again observed how through the lack of educational facilities the children of educated parents have fallen into the blackest and worst of ignorance—and I would suggest that having caught your child and accustomed him to the use of books during

his school years, it were the height of folly not to keep him so accustomed. Give him the chance never to leave his education behind, and how much of influence for good may the libraries of this country be?

I have dwelt but little on the practical side of the question—of how money is to be found for the extension of library privileges and facilities to the scanty populations—but your educational authorities have shewn how elementary educational facilities are to be extended—and I doubt not that once the library is recognised as one of the true educational factors of a community, that the state will see its way clear to do its duty.

57—SOME CAUSES AND RESULTS OF THE RECENT ADVANCE IN PSYCHOLOGY.

By W. Wybergh.

[Paper not Printed.]

58—AGRICULTURAL OR LAND BANKS AND AGRICULTURAL CO-OPERATION IN RELATION TO THE REQUIREMENTS OF THE TRANSVAAL AND OF SOUTH AFRICA GENERALLY. *

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BY J. R. K. BARKER, A.INST. OF BANKERS.

[ABSTRACT.]

Introductory. The demand for an Agricultural or Land Bank for the Transvaal.

Agricultural Co-operation the corollary of Agricultural Banks. The central and essential features of the system broadly based on mutual co-operation and virile self-help.

Agricultural Banks Generally. The Agricultural Bank of Egypt.

People's Banks and Co-operative effort. In Germany, Italy, other European countries, India and the Far East, England and Wales, Scotland and Ireland.

Agricultural Co-operation in Cape Colony. Agricultural Co-operative Expert and the practical results achieved.

Cape Government Lombard or Loan Bank. Distressful state of the Cape about 1792. Dissatisfaction, agitation, and unrest universal. Colonists in a state of rebellion. Commissioners Mederburgh and Frykenius visit South Africa in June, 1792. The objects of their mission and the powers conferred upon them. Their prolonged and patient investigation. Their supreme remedy, and its intended two-fold nature. Unbounded belief, in former times, in potency and efficacy of inconvertible paper money.

Lombard or Loan Bank founded in 1793. Inconvertible paper notes, or "cartoon money," issued to amount of £135,473. Objects, nature of business, and management of the Lombard or Loan Bank. Financial and currency expedients of the Dutch East India Co. Achievements of "high finance" in former days. The Cape taken by the British in 1795. The British promptly assure the face value of the greatly depreciated "cartoon money." The monopoly in trade abolished, and other salutary changes made. 2,000,000 rix-dollar notes in circulation in 1803, and *in good credit.* The Batavian Republic, in 1803, cancel the security, created by the British, of "cartoon money," which soon heavily depreciates in value. The Cape, in 1806, becomes a British Colony, and 2,300,000 rix-dollar notes found to be current and very much depreciated in value. The Earl of Caledon establishes circuit courts and abolishes the slave trade, etc.

Government Discount Bank, a Subsidiary State Bank, created in 1808. Capital of Bank 100,000 rix-dollars of inconvertible paper money. Objects, nature of business, and management of the Discount Bank. Lord Charles Somerset regulates the affairs of the Discount Bank. Further issues of inconvertible paper money.

3,000,000 rix-dollar notes in circulation in 1822, and which had greatly depreciated. Value of rix-dollar gradually falls from 4/- to 1/6, which represents the Cape dollar. Proclamation of 1825 establishing the British currency at the Cape, etc. Relative value of paper rix-dollar with British money. Nothing done to introduce the precious metals. Inconvertible, sterling promissory notes introduced to retire old rix-dollar notes, or "cartoon money."

The 37 years' period of depression, discontent and distress at the Cape. Proclamation of 1830, calling in the depreciated, redundant, inconvertible paper money. Proves to be a dead letter. Animated and eloquent debates in Cape Legislative Council of 1840, 1841, and 1843 on paper currency. Strong and sustained agitation for complete and final withdrawal of the inconvertible paper money. Concerted action on part of both British and Dutch colonists.

John Bardwell Ebden. The most prominent colonist of his day. Hamilton Ross and Advocate Cloete, both prominent members of the Cape Legislative Council.

Hon. William Porter, the Cape Attorney-General, was eloquent, high-principled, philanthropic, and disinterested. Called upon to defend actions of Government in regard to the paper currency. Discharges his responsible brief in no servile spirit. Conspicuous for his independence of thought and action. Opposed, on occasion, prevailing views of the Council, and not afraid to be found in a minority. Was ever courteous, and always gave valid reason for the faith that was in him.

Debates in the Council on the paper currency practically intellectual duels between the Attorney-General and Mr. Ebden. Comparison of Mr. Porter's intellectual and dialectical powers with those of Mr. Ebden. Their profound knowledge of principles of currency, finance and economics. The lawyer and the metaphysician; the practical business man with strong philosophical pre-possession.

The monopoly of the Lombard and Discount Bank withdrawn by Ordinance No. 5 of 1842. Public Banks established on the joint stock principle by leading colonists.

Cape of Good Hope Bank founded by J. B. Ebden in 1836. South African Bank started in 1838. The Directors, as a whole, were British and Dutch, respectively.

Lombard and Discount Bank finally wound up on 31st January, 1843. Chequered history of South Africa's first and only State Bank.

Proposed State Bank for Cape Colony. Various attempts to start a State or National Bank in Cape Colony. Elaborate constitutions suggested or outlined. No satisfactory method suggested for providing the necessary capital. Promoters evinced no desire or intention to personally subscribe even moderate amount of required capital.

Various Methods of Raising Capital for Agricultural or Land Banks, etc.

I. *The issue by the Government of the country of an inconvertible paper currency.* This method *not* recommended, as it is fundamentally vicious and economically unsound. The Cape Colony experienced, in the past, the serious and inevitable evils arising from an inconvertible paper currency having a forced circulation, which thus became redundant and greatly depreciated in value. A convertible or inconvertible paper currency, in our case, would ultimately require to be redeemed on a gold basis.

II. *The issue of a large loan for agricultural development purposes.* The rate of interest on Government loans depends upon the relative degree of credit employed by the Government in question. The Transvaal has relatively a large public debt of £35,000,000, guaranteed by the Imperial Government, the interest consequently being only 3% per annum. The Transvaal has also a contingent liability of £30,000,000, as a war contribution from the Colony to the Mother Country. Under these circumstances, the issue of a large loan for agricultural development purposes would be the height of financial folly; and interest at rate of 3½% per annum would probably have to be paid. The Cape Colony and Natal are able to place their Consolidated Inscribed Stock at 3½% per annum on the London Market. A loan, large or small, would have to be ultimately redeemed.

III. *The manner in which the capital of the European State Banks, strictly so called, has been raised.* The capital of the Bank de l'Etat of Russia; of the Ricksbank of Sweden, and of the National Bank of Bulgaria, was provided by the respective States out of public funds.

IV. *The capital of two quasi State Banks*—the Norges Bank (Bank of Norway) and the National Danish Bank—*was provided by levies or enforced assessment on landed property or real estate.* This principle may be found suitable to our present circumstances, as vast tracts of grazing, and agricultural land, throughout the Transvaal, held by powerful companies, etc., are not beneficially occupied. Such a levy or enforced assessment on farm property would be a legitimate and sound method in which to provide the capital of a local Agricultural or Land Bank. The principle may probably prove to be unpopular; but it is necessary to choose the lesser of two probable evils, present or prospective. The landowners would be admitted as shareholders, without further liability, of proposed bank in proportion to their contributions towards the capital fund.

A suggestion for an Agricultural or Land Bank for the Transvaal. The Transvaal Government has at hand an organisation which, if taken proper advantage of, would meet the financial requirements of the agricultural section of the Colony for considerable future period. All the monies of the "Guardians' Fund" and the deposits of the Post Office Savings' Bank should, after serving 25% to 30% in cash, be regarded as a general fund to be invested on mortgages of *farm property only.* This would be a direct and substantial encouragement of agriculture. The method of employing the funds of the

Imperial Post Office Savings' Bank is to invest them in Government Securities. As the result of this inadequate method of investing, the deposits, coupled with the fall, of recent years, in the price of Consols, there is a present deficit of £11,000,000 in the funds of the Imperial Post Office Savings' Bank. The Transvaal Government invests the Guardians' Fund and the Post Office Savings' Bank deposits largely on mortgages of town properties, particularly in Johannesburg, at 6% per annum, and comes into keen competition with private capitalists, Building, Financial, Insurance, and Trust Companies, etc., and this leads to speculative dealings in town stands and properties.

Loans granted out of the funds, referred to above, should as a rule be for amounts of about £500, and never exceed 50% of the appraised value of the *land* on which the advance is made. The object of the Government should be to encourage the small cultivators, and sternly set their face against speculative transactions. Farmers should not be induced to involve themselves with a liability they could not conveniently liquidate.

Such a modified system of an agricultural or Land Bank, as suggested above, could be conducted with great economy and efficiency. The officials are practically all ready to hand. All applications for loans could be finally dealt with by a central Investment Board. The suggested scheme is not Utopian, nor ambitious, nor difficult of attainment; but is characterised by simplicity, is essentially practicable, and only requires sound business management to render it a decided success.

The chief virtue of the scheme is that it would do an excellent service to agriculture, without incurring any fresh financial liability for the Transvaal.

Banking Advances in Agricultural Districts. The wise counsel given and the cautious considerations advanced, by a former General Manager of the Merchants' Bank of Canada, in connection with lending money to farmers. Loans may reasonably be made to buy seed, prepare the land for a crop, and to meet the expense of gathering in and harvesting the resulting crop; and also to buy such stock as will, when fattened, *be sold off the farm,* as such cases furnish from within themselves the means of re-payment. Loans should never be made to enable farmers *to pay debts.*

Government Encouragement of Agriculture in the Transvaal. Superhuman efforts have, since the British occupation, been made to promote the interests of agriculture. The colossal work of repatriation; the establishment of model farms; the importation of bloodstock; the creation of the Agricultural and Lands' Departments, all prove that the Government have attempted an entire re-organisation of the farming industry with conspicuous and encouraging success. Great praise is due. Inevitable that, in certain respects, zeal should have outrun discretion. The efforts of Government very well-intentioned, though alluring prospects of brilliant achievements have not been realized.

Lord Selborne's earnest desire to promote the interests of agriculture in the Transvaal as a productive industry. His Excellency's appointment of a Commission to enquire into expediency of establishing an Agricultural Bank, is the most recent evidence of this desire.

Banking Facilities in South Africa. The various joint stock banks in South Africa most enterprising generally. The extension of branches been distinctly progressive, so that the existing banks completely cover the field, which apparently fully occupied. Many branches in some of the small towns do not pay. South Africa's record as being better banked, on basis of its white population, than any country in Europe, and even than the United States of America. A Table was prepared to show the relative position, in this respect, at a glance.

Expenses of Management of South African Banks. The expense of conducting the business of a bank a very serious matter. Statistics, compiled by the writer, show that the cost of running the various South African Banks varies from about 50% to 68% of the gross profits.

Rates of Interest. 6% per annum is, either by statute or custom, practically the legal rate of interest throughout South Africa; and should thus be the minimum rate charged by a prospective local Agricultural or Land Bank. There is, apparently, an intimate connection between the rate of interest paid on Government loans and the ruling rate of interest charged in the open financial market of any given country. The relative ratio would appear to be, roughly, as two to one against the individual. A Table was presented to illustrate this point.

Conclusion. The object of collecting and commenting upon the data given above has been to bring together, in proper perspective, the salient features of Agricultural or Land Banks; to consider their various methods of working; and to glance briefly at the countries in which they operate. The subject has been treated, in some respects, from the general standpoint; but particular care been exercised to give the matter a direct local bearing. This has been attempted by reviewing some of the financial and currency episodes in the history of South Africa, and also by considering the actual present circumstances of the country. The experiences and failures of the past may safely guide us to a wise decision when deliberating upon certain of the financial and economic problems that confront us to-day.

59.—EUROPEAN CHILDREN IN SOUTH AFRICA NOT RECEIVING ANY SCHOOL EDUCATION.

By K. A. Hobart Houghton, B.A.

It is difficult, even with the help of the statistics of the Census Report of 1904, and the Reports of the several Education Departments for the current year, to arrive at any really accurate estimate of the numbers of European children of school-going age who are receiving no kind of instruction whatever.

From the Census Report we learn that in Cape Colony there were 43,253 European children between the ages of 5 and 14 not receiving instruction. Of these 9,926 were described as at work of some kind or other, the remaining 33,327 being without any occupation. There has been an increase of European pupils in Government-aided schools since April, 1904 (the date of the taking of the Census) of about 5,000, which may be regarded as exceeding the increase by population by about 3,000. This would mean that approximately 30,000 white children in Cape Colony, or 23.3 per cent. of the total numbers of school-going age, are neither receiving instruction nor engaged in any occupation.

In Natal there were 18,038 white children between the ages of 5 and 14. The toal enrolment in Government and Government-aided schools for the year ending June, 1905, was 11,989. Allowing that 2,000 attend private schools, we see that about 4,000 are without school instruction. At the same time, it must be remembered that a large percentage of these may be taught at home.

The following extract from the Report of the Transvaal Education Department for the six months, January to June, 1905, indicates the conditions in the Transvaal. "Figures have now been supplied by the Census Commission which indicate what proportion of the white population of school-going age within the Transvaal are benefitting by the schools which the Government has established. Owing to the transitory character of many of the schools that are opened under private management, and the difficulty of ensuring their registration and the supply of regular returns, only approximate information can be obtained as to the average number of children enrolled in these schools within a given period. Moreover, a certain number of children not enrolled in any registered school receive some form of education privately at home. A few also are sent to school outside the Transvaal. Hence it is not possible to supply in accurate figures a statistic which is still of the utmost importance, viz., the number of children in the Colony who are receiving no education at all. The following figures, however, serve to give at least an idea of the present position :—

White population between 5 and 15	62,677
Enrolment in Government Schools (June, 1905) ...	28,540
Enrolment in Schools not under Government	9,000
Number of children receiving no School Education	25,137

The Director of Education in the Orange River Colony in his Report for the year ending June, 1905, writes: "The census which was taken during the year shows that there are in the Colony 37,000 children of school-going age, i.e., from 5 to 14. The total number attending Government Schools on the 30th June, as already stated, was 15,577. The numbers attending private schools containing more than ten pupils, all of which are supposed to be registered, appear to be about 1,000. This means that over 20,000, or more than one-half of the school population, receive no instruction, except such as may be given by parents or by older brothers and sisters."

In Rhodesia about 700, or one-half the number of children of school-going age, are receiving no instruction in Government or private schools.

Summarising the foregoing, we find that the approximate number of children of school-going age not attending any school in Cape Colony is 40,000; in Natal, 4,000; in Transvaal, 25,000; in Orange River Colony, 20,000; in Rhodesia, 700, making a total for South Africa of 89,700.

Statistics of Government and Government-aided Schools in South Africa for the Year 1904-05.

	Enrolment.			Average Attendance.		Number of Schools.			Government Expenditure.
	European.	Coloured.	All Races.	European.	Coloured.	European.	Coloured.	All Races.	£
Cape Colony	68,492	100,786	169,278	61,662	80,214	1,689	1,409	3,098	447,796
Natal	11,989	13,618	25,607	9,831	10,488	279	205	484	114,430
Transvaal	27,591*a*	9,000*b*	36,591	23,180	7,631	381	172	553	306,380
Orange River Colony ...	15,577	9,296	24,873	12,758	?	258	100*b*	358	110,935
Basutoland *c*	70	14,437	14,507	?	10,484	3	225*b*	228	7,000
Bechuanaland Protectorate and Rhodesia ...	650	1,000*b*	1,650	?	?	15	20*b*	35	6,935
Totals ...	124,369	148,137	272,506	...	...	2,625	2,131	4,756	993,476

a Including about 1,000 coloured pupils. *b* Approximate. *c* 1904 census.

Joint Meeting of Sections.

Joint Meeting of Sections.

60—UNIVERSITY EDUCATION.

Editorial Note.—By special arrangement, a joint meeting of Sections was held on Friday, July 13th, for the purpose of discussing the University question in South Africa. Mr. Sidney J. Jennings presided, and there was a representative, although not a very large, attendance. By a special resolution of the Council, the discussion which followed the paper presented by Dr. Lyster Jameson is appended.

The Chairman, in opening the proceedings, explained how the meeting originated. There had been a proposal for an Inter-Colonial Conference of delegates, to be appointed by the various Governments, to consider the question of University Education, these delegates to be called together by the High Commissioner. Six weeks ago the Johannesburg branch of the Association received word from the Colonial Secretary that it would be impossible to call that Inter-Colonial Conference into being in time to have the meeting in connection with the present Meeting. On that account the Johannesburg branch of the Council felt that it would be to the advantage of the cause of higher education in South Africa if a discussion were initiated under their auspices at this meeting, where several prominent educationalists would be gathered together. Accordingly the Johannesburg branch of the Council requested Dr. Lyster Jameson, who was the secretary of the former Conference between the Orange River Colony, Natal, and the Transvaal, to initiate a discussion on the subject of University education in South Africa. He would therefore call upon Professor Lyster Jameson to open the discussion.

Dr. Lyster Jameson opened the discussion by reading a paper entitled :—

THE UNIVERSITY QUESTION IN SOUTH AFRICA.

When the Council of this Association did me the honour to ask me to open this discussion, my first impulse was to beg them to approach some member who had a stronger claim to speak on grounds of local experiences.

On second thoughts it occurred to me that it might not be altogether a disadvantage if the discussion were opened by a member of the Transvaal University College, till lately the Transvaal Technical Institute, the youngest complete University College in South Africa.

The Transvaal University College, by nature of its geographical position and other factors, is less likely to be seriously and permanently affected by any scheme of affiliation, federation or separation, than perhaps any other South African School. Its policy with regard

to these questions is not yet decided upon, and its position is consequently more independent than that of institutions whose futures so largely hang on the line of action ultimately adopted.

I therefore decided to accept the Council's invitation, and to open this discussion with a brief (and, I fear, very superficial) survey of the past history and present position of University Education in South Africa, followed by a summary of the more obvious remedies for the present acknowledgedly unsatisfactory state of affairs, leaving the discussion of the relative merits of the several schemes, or the proposal of other measures, to those who have more claim to speak authoritatively.

This is eminently a discussion, and not an address, and I will make my opening remarks as brief as possible. One of the disadvantages of the great distances between the centres of University work in this country is that we get so few opportunities of discussing questions of this kind together, and as I believe the question of an inter-colonial conference on University matters is now on the tapis, some discussion of the subject on a more informal basis will perhaps pave the way to a more definite policy. Moreover, in an open discussion of this kind we shall have the benefit, I hope, of the views of members not directly connected with University work.

The present position of University Education in South Africa is, briefly, this. There is a single University, the University of the Cape of Good Hope, which was incorporated in 1873, and received a Royal Charter in 1879. The University did not evolve out of any teaching corporation, but out of a "Board of Public Examiners," established in 1858. The Board had already for many years conducted examinations and awarded certificates in academic, professional, and technical subjects, so that the incorporation of the University chiefly resulted in the transfer of these examinations to the University and the substitution of Degrees for Certificates.

The University has remained an examining body, pure and simple, like the old London University and the Royal University of Ireland, the University of Manitoba (until recently), and, in a restricted sense, the University of New Zealand.

The growth of Higher Education in South Africa can be judged from the fact that, in each decade since the founding of the Cape University, the average number of students, graduating annually in Arts has more than doubled, so that the average for the years 1896-1905 is nearly 4½ times that of the twelve years 1874-1885. A similar steady rise is noticeable if we take averages over periods of five years, as will be seen from the following table:—

In the	period	1874-75	the	average	was	9	per year.
,,	,,	,,	1876-80	,,	,,	,,	7.4	,,
,,	,,	,,	1881-85	,,	,,	,,	10	,,
,,	,,	,,	1886-90	,,	,,	,,	18.2	,,
,,	,,	,,	1891-95	,,	,,	,,	19.8	,,
,,	,,	,,	1896-00	,,	,,	,,	34.4	,,
,,	,,	,,	1901-05	,,	,,	,,	44.6	,,

In addition to the University, several institutions, calling themselves colleges, have arisen; beginning as a rule as boys' or girls' schools, later adding work above matriculation to their programmes, and finally evolving a special "College Department," which has in some cases developed into a University College of the highest efficiency. When the separation is complete, the school, which was in a sense the parent of the College, generally becomes known as the "College School."

This evolution of a University College out of a Secondary School, which undoubtedly has certain attendant disadvantages and dangers, is the natural result of a growing demand for University work, in a country where the population is sparse and distances are great. It has, none the less, been the history of every college in South Africa, except the Transvaal University College, which was founded as a full faculty of Mining and Engineering, adding its Arts department at a later date.

In South Africa the present tendency, without a doubt, is for institutions to assume the title "University College" before they are anything more than good High Schools.

This tendency has unquestionably been fostered by our system of "Degree by Examination."

Nobody will deny that this tendency will, if unchecked, bring its own retribution in a needless multiplication of weak colleges, in a general discrediting of "University Colleges" as a class, and in a decided fall in the prestige of these institutions that have really earned that name.

To come to the individual institutions doing University work. The South African College opened in 1829 with about a hundred "students" and three "professors." The "School" was founded in 1874 as the "junior department of the College," and thus occupied buildings in the College grounds, from which it was removed in 1895. As the Matriculation classes were not transferred from the College to the School till the year 1900, the institution's life as a University College in the strict sense can be dated from that year.

The College gives Certificates in Engineering subjects, and has an Associateship. It also prepares students for the Arts Course, the Survey examinations, and the Law Examinations of the Cape University, and does the first and second years of the Mining Course; and also the first year's Medical work of the Home Universities.

During the year 1905 there were 275 students and 26 lecturers.

The Victoria College, Stellenbosch, was founded as the Stellenbosch Gymnasium in 1865. In 1874, owing to the incorporation of the University, an Arts department was established, which was incorporated as a College in 1881. The name Victoria College dates back from 1887. There is a complete separation between the school and college, and the college confines its attention to University work above matriculation. It covers preparation for the Arts, Survey and First Mining Examinations, and the first year's medical course. During 1905 there were 196 students and 16 lecturers. During 1905 the number of students was half as great again as in 1904.

The Rhodes University College, Graham's Town, is the youngest University College in Cape Colony. In 1855 St. Andrew's College was founded, and in 1878 the College and School departments were separated.

The Rhodes University College was incorporated in 1904, and took over the staff of lecturers from St. Andrew's, which was subsequently increased. The work is being carried on in temporary premises, pending the erection of buildings to cost £40,000. Three other schools in Graham's Town have occasionally put students through the Cape University examinations above matriculation, but since the Rhodes College has been established they all hand over their matriculated students to it. In 1905 there were eleven lecturers and 58 students.

The Diocesan College, Rondebosch, was founded in 1848 as a College School, and in 1886 St. Saviour's Grammar School was affiliated to it under the name of the Diocesan College School. The Matriculation Classes are still retained in the College, but otherwise the separation of College from School is practically complete. In 1905 there were five lecturers, fourteen matriculated Arts Students, seventeen Law Students, fifteen in the Survey Department, and one "miscellaneous," making a total of 47. This year there are over 50 undergraduates.

The Huguenot College, Wellington (ladies) was founded as a Seminary in 1874, and in 1898 the growth of the Collegiate Department necessitated the evolution of a College as a separate entity. The College is only open to Matriculated students. During 1904 there were 27 students, and in 1905 25 students and six lecturers. The separation between College and School is complete. Only the Arts Course is taken here.

Other Institutions in Cape Colony. By referring to the yearly pass lists of the Cape University since 1905, I find that no less than 20 schools in Cape Colony have regularly or occasionally passed students through the Intermediate Arts Examination, not including the five colleges mentioned above. Four have succeeded in putting students through the B.A., viz., Gill College, Somerset East (12), Burghersdorp Seminary (2), Kingswood College, Graham's Town (1), and Queenstown Grammar School (1). The total number of successful candidates from these schools is B.A. 16, Intermediate Arts 65. Several of these schools still retain the right of preparing students for Intermediate Arts.

Passing from the Cape Colony, we find that the only school in the Orange River Colony doing University work is *Grey College, Bloemfontein.* It was opened in 1858, and was the property of the Dutch Reformed Church till 1882, when it was transferred to the Government. Since 1899 it has put 19 candidates through Intermediate Arts and two through B.A., both the latter in 1905. It possesses a College Department, with a staff of six lecturers. The separation between school and college is complete. The classes are open to matriculated girls from the High School, as well as to the

College Students. There were in 1905 seven matriculated students, and this year there are twelve in the Intermediate Class and six in the B.A. classes. There are no other students this year, though the college offers classes for the Survey, First Mining, and Law examination. A University College, to cost £60,000, is to be built. No other school in the Orange River Colony attempts University work.

In the Transvaal the only institution seriously doing University work is the Transvaal University College, till lately known as the Technical Institute.

Within the last ten years five schools have, between them, put six candidates through the Intermediate Arts, and the Normal College, Pretoria, has obtained the B.A.

The Technical Institute began its life in March, 1904, as a faculty of Mining and Engineering, the Law Course being first started in 1905, and the Department of Arts and Science at the beginning of 1906. At present there are 91 day students, of whom 57 are in the Engineering and Mining Departments, 14 in the Arts and Science Department, and 20 in the Law Department. The staff consists of 14 lecturers, two assistant lecturers, and two demonstrators. The College grants Certificates and Diplomas in Engineering, Mining, and allied subjects, also a general certificate in Arts and Science, and an Associateship. Students are also being prepared for the Cape University Examinations in Arts, Mining, and Law.

In Natal matters are complicated by the fact that the schools occasionally or regularly prepare students for Intermediate Arts, and two or three, the Durban High School and the Ladies' College, Durban, have each on one occasion put a student through the B.A. One school, Maritzburg College, has also five successes in the survey, and two in the first Mining Examination. One or two other schools occasionally attempt the Survey Examination.

A Commission on Technical Education last year recommended the establishment of separate classes, to form the nucleus of a University College, and to draw the senior pupils from the various High Schools, where they are being coached in one's and two's for University Examinations.

The present condition of Natal's finances makes it very improbable that any steps will be taken, for the present, other than continuing the work now going on at secondary schools.

Now let us try to form some estimate of the relative importance of the several units which I have enumerated, as factors in South African University Education.

Taking first, as a basis, the Arts degree, I have plotted the numbers of successful candidates during the last eleven years along lines corresponding to the colleges from which they are derived.

In this respect the South African College and Victoria College are approximately equal, and all the other colleges and schools, plus all private students, taken together about equal in importance each of these two places.

The students, in other words, fall into three equal groups. Or we can express it this way. There are three equal educational institu tions (on basis of Arts degree), the teaching College at Cape Town, the teaching College at Stellenbosch, and the examining University at Cape Town, fed by a number of smaller schools and private students. The actual yearly averages are :—S.A.C., 12; Victoria, 12; others, 13. If we take as a basis the Intermediate Arts Examination, Stellenbosch has an annual average of 27.2, South African College of 19.7, while the greater number of competing schools, and the greater care with which the less efficient institutions can coach candidates for this examination makes the "other colleges, etc.," line considerably greater, its average being 39.

When we come to Engineering, Mining, Surveying, and Law, we find fewer competing institutions. The only Colleges regularly preparing men for the survey examination in numbers are the South African College, Victoria College, the Diocesan College and Rhodes College, while Maritzburg College has passed five, and Grey College one, in the last three years. A few other schools occasionally prepare candidates; the great majority are, however, private students.

With the exception of 3 boys prepared at the Maritzburg College, all the students who have taken the first mining examination of the Cape, and the first and second annual examinations of the Transvaal Technical Institute have been trained at the South African College, the Victoria College, and the Technical Institute. Grey College has done the work of the first year of the Technical Institute in the case of one student.

In Law, taking the senior or qualifying examinations as a basis, by far the greater number of candidates are private students, the number of such reaching to 104 last year. The average number of students graduating or obtaining Law Certificates from the South African College for the last 3 years is 29, the Transvaal University College had 30 successes last year (its first) while the Diocesan College averages for the last three years five successes, and Grey College has twice, and Rhodes College once, passed a student.

So much for the present position of University Education in South Africa. It may safely be said that the majority of those qualified to give an opinion regard the present state of affairs as unsound. We have a number of teaching institutions, of very varying efficiency, and the same degree is given, on the same terms on the one hand to the candidate who has spent three years at a fully-equipped University College, in an atmosphere of research, and in daily contact with specialists whose original works have secured them fame in their particular subjects, and on the other hand to the schoolboy who has been successfully coached, probably with deficient laboratory equipment, by men who, as schoolmasters, are usually not specialists, but at best trained retailers of second-hand knowledge. For the schoolmaster cannot be expected to attain that degree of specialisation in any one subject which is now demanded of a professor, not to create that atmosphere of research which is essential to University work, if the verdict of the leading men in the University world in Europe and America counts for anything.

The practical ways out of the present difficulty may be summed up under the headings, affiliation, federation, and separation. Affiliation would mean, I take it, to all intents and purposes, a continuation of the present regime, but with a closer union between some or all the colleges and the Cape University. Such a scheme would appear to have few advantages over the existing system, and could never be expected to satisfy the stronger colleges, though perhaps helping to bolster up some of the weak ones.

Federation is, on the other hand, a policy that many people seem to advocate, rather than separation. Federation could take place in either of two ways—there might be a wholesale federation of colleges, weak and strong, or a limited federation admitting only the most efficient.

Wholesale federation, with the admission of all kinds of colleges, would lead to a University that was in great measure an association of high schools. So impracticable would it seem, that I doubt if anyone is likely seriously to propose it as a feasible measure.

Limited federation, on the other hand, would have certain undoubted advantages, and has many supporters. The arguments for and against it have been very fully set forth in a recent "Report of Committee of Senate of South African College on University Education," a body which, as one of the pioneer corporations for University teaching in South Africa, has a strong claim be heard. On the whole, the weight of opinion in that report is decidedly against federation.

A federation of the strongest schools, preferably on an acknowledgedly temporary basis, might be a decided step towards greater efficiency. The merits and demerits of federation will, I hope, be discussed by more competent persons than myself. To me the greatest difficulty seems to be, firstly, to decide what colleges should be excluded, and, secondly, what to do with those that are excluded. That some of the aspirants to admission would have to be excluded at first is, I think, obvious, otherwise there can be hardly any doubt that the weak colleges would keep back the University, for as Professor Schuster has put it (in a letter published in the report above mentioned), "the strength of a federal university is that of its weakest college." Such a scheme of limited federation would entail a mutual agreement between the federal colleges as to the minimum of endowment, students, staff and research, which would subsequently admit a college to the federal University.

The question would then arise: What can be done with the new federal colleges, some of which may have invested considerable sums in their College Departments. They must be given a fair chance to acquire that standard of efficiency which will admit them to the federation. This could be provided for in any one of four ways:—

(1) The Federal University might affiliate whole colleges or classes or individual teachers for certain subjects and courses, either directly to the University or to one of its constituent colleges. This would absolutely exclude the weakest institutions, an object that is

not altogether a disadvantage, in view of the fact proved by the Cape examination lists, that any good grammar school can pass candidates through the present University examination. It would have the disadvantage that it would entirely exclude the private student from the advantages of the University.

(2) The Federal University might, like the London University, retain an external department (Examining University) for students from the excluded colleges, secondary schools, and private study. This scheme might not be acceptable to the student graduating from a federal college, who might resent the external man being placed on the same footing. And, to a certain extent, the existence of an external degree would defeat the main object of the federation, viz., to make work done, rather than examination results, the basis of the degree.

(3) In addition to the Federal University, the existing examining University might continue, for the benefit of external students, as an examining body. There would then be two Universities, the (Examining) University of the Cape of Good Hope and the (Teaching) Federal University of South Africa. Many of the disadvantages of a federal system would be minimised in this case, while the federation could, if necessary, be confined to three or four colleges at first, and the danger, in the event of a disruption, of the liberation as independent universities of the weaker colleges, would not exist.

(4) There might be one Federal Teaching University, confined to the strongest colleges, and that University might arrange with the University of London to hold (for the benefit of the non-federal colleges, external students and those of the internal students who desired a double degree), the external examination of the University of London, in South Africa.

Personally, I think that either the third or fourth of these measures would do justice to the smaller colleges, without handicapping the stronger institutions, except to such an extent as they might impede one another. There would be, in such a scheme, nothing to prevent a non-federal college, on satisfying the necessary conditions as to efficiency, from entering the federation at any time; while the weakest would soon know their chances of success, and some might eventually decide that it is better to be a first-class high school than an inefficient college.

I must just refer here to the possibility, discussed at a conference between the Transvaal Technical Institute and the Technical Education Commissions of Natal and the Orange River Colony last year, of a system of federation or affiliation between the Transvaal Technical Institute on the one hand, and the Grey College and the proposed classes recommended by the Commission for Natal on the other hand. So far as Natal is concerned, those classes are not likely, I understand, to come into existence at present, while the Institute has already accepted the work of the Grey College for the first year of the mining course, in the case of one student.

The alternative to federation is separate charters for such institutions as are strong enough to claim them. Two arguments are

commonly brought against this proposal; the first is that to give charters to the stronger Colleges would squeeze out the weaker. If the examining University of the Cape of Good Hope continued to exist, or if the London University External Examinations were held locally, the position of the weaker colleges would, it seems to me, be unaltered, though the stronger ones would undoubtedly gain by acquiring independence. The second objection to the granting of separate charters is the stronger one, viz., that the multiplication of degree giving institutions would lower the prestige of South African degrees. This might occur either through the cheapening of the degrees as a result of competition, a very unlikely case, and one easily provided against by mutual agreement and legislation; or through the substitution of several little known universities for one better known University. Nova Scotia, with its six (mostly denominational) universities to a population of about 500,000, and New Brunswick, with three Universities to a population of about 400,000, are held up as warnings, and the enormous multiplication of State, denominational and private Universities in the United States, with the consequent lack of prestige in American degrees, unless granted by one of the leading Universities, is often cited.

The same arguments might be brought to bear against the recent multiplication of Universities in the British Isles. Everybody will admit that the multiplication of Universities has reduced the prestige of University degrees, which, while fifty years ago, they were practically a perquisite of the leisured and professional classes, are now within the reach of almost everyone; but the loss to the individual in the lessening of the market or social value of his degree is far more than compensated by the gain to the community in the growth of the great "City Universities." I think it is probable that there would be similar compensating factors in South Africa.

If it came to the question of independent charters, there seems to be, according to the Arts Course figures, two institutions in Cape Colony that have a reasonable claim, in addition to the remaining University of the Cape of Good Hope, viz., the South African College and Victoria College.

The position of the Transvaal Technical Institute will determine itself better in the next year or so, but it seems to me that its distance from the Cape Peninsula is the strongest argument against its connexion with a general federal scheme being anything more than temporary. The policy of the Transvaal Technical Institute in this matter is not yet definitely determined, though there are reasons for believing that a federal scheme, provided the status of the best colleges were not imperilled by association with weak institutions, would suit it, at least as a temporary measure. The Rhodes University College, like the Transvaal Technical Institute, might benefit most by such a scheme, though I have no doubt its policy will be clearly described in the discussion.

As I said at the commencement of this paper, I prefer to leave the advocacy of the different measures, and the detailed discussion of their merits and demerits, to those who have borne the heat of the

day in the Educational field of South Africa. May I be permitte to say, however, that, however great the disadvantages of federatio on the one hand, and of separation on the other, the greatest per to University Education in South Africa lies in the excessive multipl cation of institutions with poor endowment and small, underpaid an over-worked staffs, and in the too lavish use of such high-soundin titles as "University College" and "Professor"; a course which if followed much further, would inevitably lead to a lowering of th ideals of University teaching, and to such a change in the status o the University teacher that South Africa will have great difficulty i obtaining, as she must be in a position to do, the best men the Empir can offer, to fill the academic chairs.

Professor L. Crawford (Cape Town), who was the first speake on the paper, referred first to one or two points of detail. Th Huguenot College, he stated, was not entirely confined to lad students. Male students were also admitted, under certain condi tions. Then, again, in connection with Natal; there was on encouragement given in Natal to go on and take their students beyond the Matriculation. There was a Mining Scholarship of £80 fo four years, to enable a student to go through a complete mining course. The examination for this was the Intermediate Examinatio of the University of the Cape of Good Hope, so that all candidate for this scholarship were forced to read for that examination.

Proceeding to deal with the general question, the speaker too it as hardly in need of further proof that the present system wa unsatisfactory, but, before passing on to the consideration of th remedies proposed, he pointed out one existing drawback—the encour agement given by the present conditions to cramming. He could speak from experience on this point, and could name various student who, having taken things very easily for about three-quarters of th time, had at the last moment, thanks to the possession of some ability crammed up and successfully passed the examination, and had bee granted precisely the same degrees as those who had done reall solid work throughout the whole course. Some check on the student was necessary to ensure that every degree should imply honest wor throughout the whole course.

With reference to affiliation, he would read the Memorandum o the Rhodes University College, as he believed it was the fullest state ment hitherto made of the case for affiliation, and the best explana tion of what affiliation really meant.

(The speaker here read the "Memorandum of the Counci and Senate of the Rhodes University Reform.")

Continuing, the speaker indicated the reasons which, in hi opinion, rendered an affiliation scheme useless. The only advantag seemed to him to be that the Colleges were to be more directly repre sented on the Senate of the University. That would be an advantage provided the principle were extended. The Senate of the Universit should not consist merely of representatives of the Senates, but o all members of the Senates; these must be present for any discussion of details. There was still to be a University Council, which would,

of course, be the chief executive body, so that the present difficulties —which, in some cases, were rather exaggerated—with that body would remain. If, as the memorandum seemed to contemplate, many more institutions were founded, we should get, as Dr. Jameson said, really an affiliation of High Schools.

Coming to the federation scheme, Dr. Jameson had pointed out that there were two kinds of federation, the one a federation of all the colleges at present in existence, which would almost imply that any others to be hereafter founded should also be federated. Then there was the other kind of federation—the proposal that the stronger colleges should federate and become one University. The difficulty in this case was—what were they going to do with the present University? But before they got to that difficulty there was a still stronger one. If they were going to have a limited federation—a federation of the stronger Colleges—who was going to decide which were the stronger Colleges, and whether a particular College should be admitted to the federation or not? It was all very well to say that before a College was admitted there must be a sufficient equipment and endowment, and a sufficiently good teaching staff, but who was to decide on these points? It might be suggested that the Governments should make the selection. The Governments would probably appeal to the Superintendents-General of Education. Such an appeal might put the Superintendents-General in a very invidious position. In Cape Colony, one might suppose, the Superintendent-General considered that all the Colleges were doing sufficiently good work, since he was supporting them all. The difficulty in connection with federation, or one of the difficulties, was the formation of the federated body.

There were two kinds of federation possible, even if they were to confine themselves to federating the stronger Colleges. There was the ordinary federation which existed in the Victoria University, and which he believed existed now in the University of Wales; in fact, he believed the University of Wales was now practically the only type of Federal University in existence. He described the nature of the examination system in the University of Wales. Practically, the examinations were the same. Slight alterations were allowed, but the examinations were practically common to the three Colleges which formed the University.

But there was a totally different proposal in connection with federation which had been put forward by the Victoria College, Stellenbosch, and he did not think that had been taken into account by Prof. Jameson. It would therefore be interesting to point out what their scheme was.

(The speaker here read the leading features of the Memorandum on University Reform, issued by the Council and Senate of the Victoria College.)

A federal system had undoubtedly caught the public fancy. Anyone who was present, as he was, at the discussion by the Convocation of the University on the different schemes, could see that unquestionably the federation scheme commended itself to the public. The idea which appeared to be taken up was that as a matter of

course a Federal University must necessarily be a strong University. A good many people seemed to consider that if four Colleges were federated into a University, they must perforce get a University four times as strong as any one of the Colleges! Dealing with the drawbacks of the federal system, the speaker alluded to the question of the distance between the various institutions comprised in the federation. In Wales, of course, distances were not very great, but the difficulty from this standpoint would be enormously accentuated in any scheme of federation designed to include the whole of South Africa; in fact, in any scheme of federation which could be carried out in this country. Even if the Transvaal decided to stand out, and they were only attempting to federate the Colleges in Cape Colony, this difficult would still be felt. Then there was the further difficulty that institutions in different parts of the country might want to develop in different directions. Under federation, Colleges might want to discuss schemes in which they were taking no actual part. Such a position would mean that constant compromise on various points would be necessary in order that progress might be effected.

Then, if they were going to have common examinations, they would have a further drawback by reason of the rigidity of that system, but this would disappear if they adopted the Stellenbosch scheme, and had separate examinations for the separate Colleges. He would like to make one or two remarks on this proposal, because it might commend itself to some who objected to separate Universities, and yet recognised the difficulties in connection with the usual federation scheme. The difficulty in connection with this proposal was that if each federated College was conducting its own examinations, the examinations of the different Colleges would be, of course, of a different standard. An effort might be made to keep them to the same standard, and a fair degree of uniformity might be attained, but they would certainly not have the same standard throughout. At the end of the year something like fifty graduates, who had been examined by different Colleges, would be sent out, all with the same degree, though they had not passed the same examinations, and though the standards might have varied to either a slight or a comparatively large extent, as the case might be. In his opinion, this was a distinct drawback. If there were to be entirely separate examinations, then the men ought to be able to say at what College they had been educated, and the degree ought to show at what place the work had been done. They would then be much more likely to maintain the standard, because he did not think that the various institutions would adopt the suicidal policy of trying to cheapen the examinations. If, however, they instituted separate examinations, why should they not take one more step forward, and decide that each College should give a separate degree? The Council of the Victoria College had recognised that, as shewn by the second clause of their memorandum, expressing the conviction that, failing the adoption of the amendments which they recommended, the existing University should be dissolved, and separate charters granted to certain Colleges to be named by Parliament.

What was going to happen in regard to the private student? In South Africa we must expect to have the private student difficulty with us for many years to come. No scheme could be regarded as complete which did not in some way take into consideration the private student. He did not think that in a federal scheme, an external student, who had not studied at any College, should get the same degree as a College student. They should be able to know in some way whether a man had gone through a complete course at College, or had merely taken a degree by examination. As to Professor Jameson's suggestion in regard to the London examinations, that might be adopted in connection with Arts; it would, however, rather encourage the private student, and he thought they should rather try to induce men to enter the Colleges.

Coming to the considerations involved in the proposal for separate charters, he thought these were fairly well known. Prof. Jameson had pointed out the danger of too many Universities—the possibility of lowering the prestige, etc. He thought that the danger had been a little exaggerated. South Africa, up to the Zambesi, was not by any means a small place, and the fact that there might be six Universities in Nova Scotia, which was in excess of its population, was not a very strong argument against having perhaps in the future six Universities in South Africa. He did not think there would be the danger in the long run of lowering the degree. There might be some such danger at the beginning, perhaps, but he was not sure of that. He was, however, quite sure that if any such danger existed at all, it would work itself out in an exceedingly short period. Stress had been laid upon the danger in the United States, arising from the number of institutions there. He thought, however, that it was pretty well known which were the good degrees, and which the bad. He believed that in practice that danger would to a large extent disappear, and that it would be recognised which Colleges were giving a good degree.

He did not quite agree with what had been said as to the lowering of the value of the University degree in the Old Country owing to the number of Universities founded. In the old days, of course, a University degree in the Old Country meant a degree at Oxford or Cambridge. But Oxford and Cambridge degrees had a certain value of their own, and might be left out of account in discussing the kind of Universities we should be likely to have out here. The institutions founded in this country would approximate much more nearly to the Scotch Universities or the newer Universities in England. He believed that if there had been any slight lowering in prestige—and that he doubted very much—by the multiplication of institutions granting degrees, it had been quite overborne by the fact that the possibility of taking a real University course in the Old Country was so much wider now than in past times.

Rev. Dr. Kolbe (Cape Town) said the tone in which this question was sometimes discussed seemed to imply that the members of the University Council were a lot of old fogies, sitting in the seat of the

scornful, and determined never to move. As a matter of fact, they had been looking forward to the necessity of a change of this kind for a long time past. He might remind the meeting that there would have been no possibility of even such a discussion as this until the Colleges were in existence and properly equipped. The discussion really originated in the heart of the University Council itself. They all entered fully into the discussion, and a committee of the Council was appointed, of which he was a member, to formulate some scheme of improvement.

His view might perhaps be somewhat unwelcome to the majority, but he felt bound to confess, while disclaiming any desire to sit in the seat of the scornful, that he was rather for moderation in any forward movement. He doubted if they had yet arrived at the stage when they could take a very gigantic stride. He had, however, been for years in favour of steady and gradual progress in the direction of drawing the various Colleges more closely together. For many years he had advocated that professors and teachers should be examiners, and that Colleges should have something to say as to whether the student should get his degree or not. They might therefore look upon him as having been for many years in favour of steady, moderate improvement, although at the present moment he was in opposition to any violent change.

It appeared to him that during the present discussion several things had been tacitly assumed. One thing which had been assumed was that their University was in exactly the same position as that of London when it was purely an examining body. There was this difference—that while it was true that the Cape University was an examining body, it was an examining body which was almost entirely in the hands of the Colleges themselves. The University Council was predominantly made up of the representatives of the three Colleges. The examiners were selected by them. It was purely by reason of an Act of Parliament that the examiners were not selected from them. But the examiners were selected by them, and the syllabus was drawn up in accordance with their instructions. The whole thing was practically in their hands. There were other elements in the University, which filled a gap, for, after all, the Colleges were not Universities in the real sense of the term. The attempt had been made by the University Council to represent every intellectual interest, every educational agency, every forward movement in the intellectual life of the country. It might be a very bad attempt, but if anyone could show them how to do it better they would be grateful.

Another assumption was that either there must be affiliation, or federation, or separation, or, failing either of these, the *status quo*. Now, there was, logically speaking, a gap here. A little possibility had been omitted. It was perfectly possible to evolve, but the *status quo* would not remain. The Council was now a different organisation to what it was years ago. Progress had been more rapid during the last few years than for fifteen years previously, and it had been in proportion to the progress of the Colleges. Now that the Colleges

were taking up a higher standpoint, the chances were that future progress would be more rapid still. For example, formerly the Committee of Studies was appointed purely from the Council itself. Now they brought in assessors from the Colleges, who were becoming more and more specialists, the subjects for study being left more and more in their hands. The latest development was to give them a vote, so that for all practical purposes they were members of the Council, and had almost as much to say as the members themselves. When these specialised reports came before the Council they were very rarely thrown out. It would be seen, therefore, that already there was an evolutionary movement going on. The bond between the University Council and the Colleges was being drawn closer, and this, he submitted, was a process capable of being very much further developed. It was just possible that they would spoil that movement by any violent action at the present time. If they had teachers examining, if they had professors' certificates contributing towards the degree, if they had the syllabuses drawn up entirely by the professors, then federation would be almost superfluous. There was no question of the old *status quo* being maintained. The question was one of gradual progress by evolution until they reached a better position. If they took violent action now they would be bound by it. If, on the other hand, they continued to draw closer the bonds of union in the way he had described, they might in five or ten years' time see a solution which did not exactly reveal itself at present.

A further assumption was that their sole function had been examination. If that were the sole purpose of the University, he would be very sorry to belong to such an institution at all. He had no particular belief in examinations, and still less in their results. If that were all, he should not care about the continuance of the University. But what they had done—what they knew they had done, by the testimony of teachers all over the country—was to very largely stimulate education everywhere, in a way in which no College could have done it. They had the Schools, and they had the pupils. It was possible, of course, that the exaggerated idea which people had of certificates was very useless, but it had at all events had this great advantage—that it had persuaded parents to make sacrifices for their children, and education had been very largely extended throughout the country, especially in the smaller places. They received constant tributes from the teachers, saying how much they had done towards raising the standard, and making the possibility of University Education practicable. After all, what was the use of a University without students, or of students without preliminary training? The University had still great possibilities before it in the direction of increasing this stimulus, and if the present system were broken up a great deal of this stimulus would disappear. It might be that they had arrived at the point when it was no longer necessary for them to stimulate, but he did not think so. Such a record as they saw on the charts before them seemed to show that the contrary was the case. He was constantly preparing for the higher examinations young men who had failed to get opportunities

for University education in their younger days. Over and over again he had trained for the Survey, for the Intermediate, and for the B.A. young men, and sometimes young women, who wanted to take their degree. Moreover, there were other lines on which the Colleges had nothing to say at all, and had made no provision for. There was the training of teachers, for example. Men in his position felt that the time had hardly arrived when they could be rightly and properly thrown into outer darkness. They were, at anyrate, doing a great deal to stimulate education. They might not be a College, but they were doing a great deal of the work which, in a country like this, Colleges would otherwise do. In an established and large community they could, given the necessary means, create a College or University. In this country they had not the students. What would be the use of a magnificent University without the students? The preliminary work was still being done. It was progressing as rapidly as could be expected. The students were even more necessary for a University than the professors themselves.

The University Council, as at present constituted, was in touch with all the learned professions, which the Colleges were not. The University was stimulating that foundation work which the Colleges could afterwards build upon. What were the Colleges themselves doing in regard to the learned professions? Hardly anything for Law. The University was only waiting for the medical profession to give the word, in order to make provision in this respect. In regard to Theology, they were hoping to establish a definite degree. There were not yet the educational facilities necessary for it, but establish the degree and the other was stimulated to follow. After all, they did not want the University to be a mere Science field. There was something else in the world besides Physical Science.

The tendency was for Science to become so paramount that the other refinements of life were almost thrust out—Music, Theology, Philosophy, Medicine, and other branches of learning were as essential for human progress and development as Science ever had been.

He would vote, not for revolution, but for evolution, in the educational forward movement. He saw signs that the movement was making progress. The evolution should be from within, and not from without. He did not wish to dictate, but he would point out that since Natal came into line with Cape Colony there had been a very strong forward movement. If the Transvaal and the Orange River Colony would also come into line with them, take a share in their endowments, compete with them, and send their representatives, then this evolutionary movement would proceed from within by the development of the possibilities and actualities of the position as it stood to-day. The Transvaal and Orange River Colony should be represented on their Council and bring to it that wisdom which it was known they so abundantly possessed.

They must go quietly forward. They had not yet arrived at the time when they could suddenly plank down a building and say,

"There is a University for you." In the first place, they had not the endowments, and, in the second place, they had not the students. We were a small community after all, although so widely scattered, and if they brought their Colleges closer together he felt sure that in a short time they would reach a standpoint from which they would be able to see the lines future evolution would have to take.

Professor Lehfeldt (Johannesburg) said he thought the meeting had gained by listening to the remarks of the last speaker, representing the Cape University. If they looked forward to see what the ultimate aim must be, he thought there could be only one answer. The only kind of University that had ever succeeded was the University which was situated in one place, which had a corporate existence, and had a staff and students who knew each other, and could create that interest in study and research which was so essential. The essence of a University therefore appeared to be that it should be bound up with a particular locality.

There had been previous attempts at creating Federal Universities, and they had served a purpose, but these Federal Universities had nearly all broken up. According to Professor Crawford, the only one which practically survived was the University of Wales, and that could at the best be only a passing phase. A University essentially implied a something which was located in one place, and had an intimate, individual life.

The name "University" had unfortunately, of late years, been given to certain institutions which were not Universities. He did not wish to discredit the Cape University in any way by saying that it was one of those institutions. The Cape University had done good work for education in South Africa, and was evidently continuing to do so, and, according to the information of the last speaker, the managing body were very open-minded, but it was not in any real sense a University.

The only ultimate object which one could see for the evolution which that institution was helping to bring about was the establishment of real Universities—of a moderate number of real Universities in South Africa. It could not possibly be content with one University eventually. The difficulty arose from the smallness of the population, and the fact that it was scattered over so wide an area. It was difficult, on the one hand, for such a population to make use of one or two Universities, and, on the other hand, to provide for a sufficient number.

Of all the various schemes put forward, he thought the one which had been recommended by Stellenbosch came the nearest to what he would himself suggest. But he wished to offer one or two criticisms on that proposal. There were two opposite extremes. One was a weak affiliation, which could not do anything considerable to stimulate the activity of particular localities. Perhaps he ought to say that the extreme in that direction was the idea of the present Cape University. It would give no very strong stimulus to the creation of the local atmosphere, of the local conditions, which were

really the essential spirit of the University. The opposite extreme was the attempt, which a good many had regarded as premature, to establish a number of separate Universities. It was perhaps hardly time for that. But he thought there was less disadvantage for the future of South Africa in the establishing of several weak Universities than in the absence of any genuine Universities at all. Professor Crawford had discussed that point, and as he (the speaker) was in agreement with him, he would not repeat the arguments.

But between these two extremes there came in what he thought would be the best possible line which evolution could take—the grouping together of a few institutions, to support one another in the establishment of the necessary reputation. He had only been three months in South Africa, and he could not speak with authority on local conditions, but he could perhaps say one or two words regarding South Africa as it appeared to those outside, better than those who had lived here for a long time. And he felt bound to be somewhat emphatic upon this point—that it was necessary to establish a reputation in South Africa for University Education. Their existing institutions had not a very good reputation at the present time, and it seemed to him that the best hope for the future was to strengthen the hands of the few institutions which were trying to do real University work. There were two or three institutions which would hardly deserve to be called Universities. They required buildings and endowments, but, more than all, they required the best possible staff. Everything depended on the men who had the work to do. Such a movement would help to get good men, to get more money to pay them with, and to give them better positions by being professors in independent Universities. The institutions also required to take all the Faculties into consideration. On that point he entirely agreed with the representative of the Cape University. He would not admit any institution as being a University unless it had several faculties represented.

It seemed to him that they might take the three or four institutions which satisfied those conditions, and although they might not be quite strong enough at present to become independent Universities, they would help one another, provided they were formed into a group sufficiently loose to enable them to develop their own individuality, for individuality was as necessary for a University as for a person. One of the greatest drawbacks of federation or affiliation on ordinary lines was that it compelled the various component parts to be alike. They did not want them to be that. He thought the requirements might be met by a scheme something like that put forward by Stellenbosch, but he would prefer that it should not be in connection with the existing University. The existing University had other duties. But it was essential to adequate development that the different Colleges should hold their own examinations, subject merely to criticism. If they had absolutely independent Universities, criticism failed. But they would be able to maintain a fairly level standard by appointing external examiners, and if there were several

Colleges grouped together they could criticise each other, each examination being conducted by a professor in conjunction with a specialist from one of the other institutions. That would tend to make matters fairly even between the different bodies. He would like to see a common degree at the present time—and it might be for a quarter of a century or so—a common degree granted on the strength of the work done at any one of the few institutions which shewed themselves capable. If these institutions attained anything like the standard of a University, they would get much more support. He submitted that the best way of evolving improvement out of the present situation was to leave the Cape University to do the useful work it was at present doing, but to grant a position of semi-independence to those institutions which were capable of being brought into the limited scheme of federation which he had suggested.

Mr. J. M. P. Muirhead (Cape Town) said he would like to offer a few remarks on the practical aspect of the question. It was all very fine for professors of different Colleges to meet and discuss how many Universities they were going to have in South Africa, but the main point was to prove to the people of South Africa that these institutions were necessary, and that the expenditure involved would be justified. It seemed to him that from the standpoint of the man in the street the facts and statistics before them at once did away with any hope of obtaining very much support from the public for more than one University at present. If the South African College and the Victoria College combined their students, there might be sufficient to justify the founding of a good teaching University, and the Transvaal, having made a good start, might also in time be entitled to a charter. But to suggest, with 800 students all told, that half a dozen Universities should be kept up, with all the dignity of buildings, chairs, endowments, etc., might commend itself to the academic mind, but in the present condition of the country was not likely to be approved by responsible legislators. They would, first of all, have to demonstrate the necessity for making a change. They had heard from Dr. Kolbe that it was not necessary to preserve the *status quo*. The Cape University was willing to go forward as far as lay in its power, and under these circumstances it seemed to him (the speaker) that they would have very great difficulty in persuading anyone outside that there were reasonable grounds for establishing further Universities in South Africa at the present moment. The general public, with past experience of American degrees before them, were not going to be very keen about multiplying degree-giving institutions.

It was also an axiom that they should strengthen what they had before seeking to add to the number. Surely in a country like South Africa it was infinitely better to have one good, strong University. And there was surely no reason why the Cape University, which at present was almost solely an examining body, should not in time become a teaching one, even if it swallowed up the South African College.

The voice of the ratepayer should be heard on this question. He was quite convinced that nothing had been said there that day, and no figures had been produced, which would justify the Legislature of Cape Colony in endowing a fresh University—at anyrate, for the present.

Mr. J. Lyle (Bloemfontein) remarked that perhaps the best contribution which he could make to the discussion would be to say a few words as to the position which the Orange River Colony intended to take up in the matter. He asked Dr. Kolbe to take from the Orange River Colony to the University Council their thanks for the politeness and courtesy with which the Orange River Colony had always been treated. They had always found that the Council was willing to give them every consideration, and, in fact, had sometimes gone out of its way to consult them. The Council was always ready to act on any suggestions brought forward, although up to the present the Orange River Colony had not become a "contributing colony." They in the Orange River Colony had always discouraged the attempts of High Schools to become Colleges, and to profess to give University education. They had found it wise to concentrate all their energies on the Grey College, Bloemfontein. This institution was founded fifty years ago by Sir George Grey, with the purpose that it should be a University College. In the deed of gift this was stated most distinctly. It was intended for the training of teachers, ministers, and men who wished to enter the learned professions, although the intention had not been adhered to. A very striking thing was the almost pathetic love which the people in the Orange River Colony had for this College. It was only natural, therefore, that they should concentrate all their efforts on developing the possibilities of this institution. He should like to support Dr. Kolbe in his statement that the Cape University had shewn not only the capacity, but a great desire to evolve along the lines making for efficiency, and for the maintenance of a proper standard of University education in this country. A few weeks ago the Orange River Colony, Transvaal, and Natal were represented at a meeting in Cape Town, at which he was present, and, when writing his report of that meeting, he actually put down that they met there the representatives of the Victoria College, the Rhodes University College, and the South African College, whereas he was told they had actually met a committee of the Cape University. Thus they would see that the University consulted the professors.

The Orange River Colony had now almost decided to become a contributing colony, and, if their negotiations were successful, would be represented on the Council. It seemed to him that the other Colonies should do the same. For a paltry sum of something like £200 per annum, a Colony could become a contributing Colony, and have three representatives on the Council. He would suggest that the policy pursued by the Orange River Colony should be adopted by the other Colonies. They admitted, of course, that the present system was not satisfactory, but they must not too hastily assume

that the only way of mending it was by ending it. The suggestions for mending the Cape University by ending it only accentuated the need for its existence. Do what they liked, and suggest what they liked, the question of the private student, the question of how to deal with the sparsely-populated districts of the country, would still trouble them. It would not do to set up a few Colleges and expect parents in remote localities to send their sons to those institutions. Their policy should be directed towards bringing University education within the reach of even the humblest person in South Africa. This, as the facts before them shewed, had been adequately done by the Cape University. The increase in the number of degrees shewn upon the chart before them was very striking. Nor had that been done by retarding the growth of any of the Colleges. The speaker concluded by reiterating that they in the Orange River Colony thought that the best interests of education in South Africa would be served, for the next twenty or thirty years, by a whole-hearted devotion on their part to the Cape University.

Professor Bohle (Cape Town) asked what provision was going to be made by the Cape University in regard to engineering. At present, mining engineering was the only branch of the subject in which examinations were held. Engineering was, and would continue to be, one of the most important professions for which provision could be made in this country. With the exception of Mining, the Cape University had made no provision, and, so far as the mining classes were concerned, he did not think that the examinations held were at all satisfactory. They had, at the end of a complete course, an examination lasting three or four hours. That was not at all satisfactory. They could not examine an engineer in three or four hours. After a complete course, he should be able to write out a proper thesis on special work. So far as he was aware, they appointed for the mining examinations an outside examiner. The outside examiner was usually a specialist in some particular subject, and a specialist was not the proper person to test the general knowledge of the student. It was only a professor, and preferably a professor of some other College, who was able to examine a student properly. A specialist would content himself with putting questions in the subject with which he was best acquainted. Apart from this, he (the speaker) was anxious to know what the Cape University intended to do with regard to other branches of engineering. The South African College had started an engineering department, and he would like to hear from Dr. Kolbe what was the intention of the Cape University with regard to electrical, civil, and mechanical engineering.

Professor Wilkinson (Johannesburg) laid stress on the fact that a University was not merely a teaching institution, but embodied the spirit of research. He pointed out that if Professor Lehfeldt's idea of federating selected Colleges were carried out, they would have a teaching University side by side with the present examining body, and if it became a struggle for supremacy between these two, there

was not the slightest doubt as to which would emerge triumphant. What they wanted was not merely an examining body, but a teaching University, and one in which the staff would not be merely on the plane of ordinary schoolmasters, but would be able to devote a considerable proportion of their time to the advancement of research.

The Chairman asked if any other gentleman present wished to express his views. There being no response, the Chairman went on to say that he would like to make a few remarks himself.

His point of view would be the same as Mr. Muirhead's—that of the man who had to pay—or, rather, who had to solicit other people to find the money. South Africa had a population, roughly speaking, of a million white inhabitants, and about six million blacks. It could be taken as a fact that the average white inhabitant of South Africa received a larger income than the average inhabitant of England or Germany. Roughly speaking, a population of a million people in South Africa would about correspond, in fee-paying capacity, to a population of two millions in Germany or England. Now, if they considered the number of Universities in those countries, they would find that a million inhabitants could support a University. It therefore seemed to him to be within the range of possibility that South Africa could support two Universities. That was the first point they needed to arrive at. Secondly, there was the question of the conditions under which their University was going to be constituted, and here it seemed to him to be of the highest importance that the personal staff should represent the highest possible standard, and should exemplify that attractive personal magnetism which made the student learn in spite of himself, and inspired him with that ardent desire for research, to stimulate which appeared to him to be the true function of a University.

He did not wish to trench upon the province of those who had devoted their lives to the furtherance of education, but his own personal feeling was that in carrying out any scheme for the creation of a University, the test of the work actually done should be of equal, if not of more importance, than the results of the examinations. With regard to the question of ways and means, he was afraid they would need many discussions such as had been held to-day before they would be in a position to carry their ideas into effect. The present discussion, however, would no doubt be helpful, in view of the conference which was to be held, approximately, within the next two months. He had been glad to observe that the discussion had proceeded on the broad plane of an amiable desire to find out what would be best in the interests of South Africa as a whole, and that the speakers had not merely set themselves to advance the interests of the particular institutions with which they happened to be connected.

Professor Lyster Jameson then replied on some of the points raised. He was afraid that in certain respects one or two of the speakers had not quite grasped his ideas. He pointed out that he

did not lose sight of the fact emphasised by Dr. Kolbe, that the Cape University might evolve slowly in the direction they desired, and he disclaimed any intention to advocate that they should mend the Cape University by ending it. In fact, in every one of the possible schemes which he brought forward he tried to avoid taking the Cape University into account, either in its present capacity, or modified as the centre of an affiliation scheme, or alongside of the teaching University. Professor Crawford seemed to imply that he had suggested that the multiplication of Colleges in the United States was a disadvantage. He would not like to say that. He did not know what public opinion was on the subject, and rather hoped the Chairman would have been able to tell them. He believed that one per cent. of the population in America had received a University training, and that this one per cent. held 40 per cent. of all the leading positions of trust and responsibility. It was probably owing very largely to the multiplication of Colleges that there was such a large percentage of College-trained men holding these positions of trust.

PROGRAMME OF FOURTH ANNUAL MEETING, KIMBERLEY, 1906.

The following is an epitome of the programme of the Fourth Annual Meeting, held at Kimberley, July 9th-14th, 1906:—

MONDAY, JULY 9TH.

3 p.m.—Meeting of Council.
8.30 p.m.—The President's Address at the Town Hall.

TUESDAY, JULY 10TH.

9.30 a.m.—Meetings of Sectional Committees.
10 a.m.—Meetings of Sections.
2.30 p.m.—Tour of De Beers' Mines, Crushing Mill and Pulsator.
8.30 p.m.—Lecture at the Town Hall by Professor R. A. Lehfeldt, B.A., D.Sc. Subject: "The Electrical Aspect of Chemistry."

WEDNESDAY, JULY 11TH.

9.30 a.m.—Meetings of Sectional Committees.
10 a.m.—Meetings of Sections.
2.30 p.m.—Meetings of Sections.
8.30 p.m.—Reception and Dance at the Town Hall, by invitation of the Mayor and Town Council of Kimberley.

THURSDAY, JULY 12TH.

10 a.m.—Visit to Wesselton Diamond Mine to view a blast, and to Kenilworth Village, by invitation of the De Beers Company.
1.30 p.m.—Luncheon at the Kenilworth Club, by invitation of the De Beers Company.
4 p.m.—Meeting of Council.
4.30 p.m.—Annual General Meeting of Members.
8.30 p.m.—Lecture at the Town Hall by W. C. C. Pakes, L.R.C.P., M.R.C.S., D.P.H., F.I.C. Subject: "The Immunization against disease of Micro-organic Origin." (A resume of modern methods of combating certain preventable diseases).

FRIDAY, JULY 13TH.

9.30 a.m.—Meetings of Sectional Committees.
10 a.m.—Meetings of Sections.
2.30 p.m.—Meeting of Members to discuss the question of University Education in South Africa.

SATURDAY, JULY 14TH.

5 p.m.—Departure of special train conveying party of Members to the Victoria Falls.

At the Sectional Meetings the following papers were read:—

SECTION A.

TUESDAY, JULY 10TH.

President's Address, by J. R. Sutton, M.A.

On the Observation of Earthquakes and other Earth Movements.—Prof. John Milne, F.R.S.

New Monthly Cloudiness Chart of the United States.—Kenneth S. Johnson.

A New Solvent for Gold.—James Moir, D.Sc., M.A., F.C.S.

WEDNESDAY, JULY 11TH.

Anticyclones and their Influence on South African Weather.—Col. H. R. Rawson, C.B., R.E.

The Barometer in South Africa.—R. T. A. Innes, F.R.A.S.

The Manurial Needs and Resources of the Transvaal.—Herbert Ingle, F.I.C.

On Predicting Times of High Water at Durban, Natal.—R. F. Rendell, B.A., F.R.A.S.

Recent Cometary Observations.—R. F. Rendell, B.A., F.R.A.S.

Some Meteorological Conditions in Bulawayo.—Rev. E. Goetz.

FRIDAY, JULY 13TH.

Magnetic Observations in South Africa.—Prof. J. C. Beattie, D.Sc., F.R.S.E.

Temperature Variability in South Africa.—J. R. Sutton, M.A.

The Acceleration of Gravity at Johannesburg.—Prof. R. A. Lehfeldt, D.Sc., B.A.

SECTION B.

TUESDAY, JULY 10TH.

Geography as a Factor in Higher Education.—Frank Flowers, F.R.G.S.

The Glacial Beds in the Griquatown Series.—Arthur W. Rogers, M.A., F.G.S.

The Negro in America.—T. Lane Carter.

Witchcraft and its Customs.—Rev. H. A. Junod.

A Contribution to our Knowledge of the Stone Age in South Africa.—J. P. Johnson.

WEDNESDAY, JULY 11TH.

The Distribution and Variation of the Tortoises of South Africa.—Prof. J. E. Duerden, Ph.D., A.R.C.S.

"Modjadje": A Native Queen in Northern Transvaal.—Rev. F. Reuter.
Infectious Experiments with Uredo Graminis, Pers.—J. B. Pole Evans, B.Sc.
Features in the Vegetation in South Africa due to Prevailing Winds.—Dr. R. Marloth, M.A.
Sunrise Moisture and Growth.—Col. H. R. Rawson, C.B., R.E.
Somabula Diamond Field of Rhodesia.—F. P. Mennell, F.G.S.

FRIDAY, JULY 13TH.

Immunity in Certain Wheats to Rust.—J. B. Pole Evans, B.Sc.
The "Black Rust" of Wheat, etc.—J. B. Pole Evans, B.Sc.
Death Feigning in Ostriches.—Prof. J. E. Duerden, Ph.D., A.R.C.S.
The "Black Spot" Disease on Apples and Pears.—J. B. Pole Evans, B.Sc.
Some South African Cycads: their Habitats, Habits and Associates.—Prof. H. H. W. Pearson, M.A., F.L.S.
Notes on the Systematic Description of the Transvaal Amaryllids.—Miss R. Leendertz.
Petrography of the Rocks surrounding the Diamond Pipes of the Kimberley District.—R. H. Restall, M.A., F.G.S.

SECTION C.

TUESDAY, JULY 10TH.

President's Address by Sidney J. Jennings, M.I.M.E., M.Amer. I.M.E., M.I.M.M.
The Realm of Alfalfa.—S. Hodder.
Smoke Abatement in Mining Centres.—Arthur H. Reid, F.R.I.B.A.
South African Horticulture.—T. R. Sim.
The Arnold-Bragstad-La Cour Polycyclic System of Current Distribution.—Prof. H. Bohle.
An Underground Traverse.—A. E. Payne, A.R.S.M.

WEDNESDAY, JULY 11TH.

Further Experience in the Bacterial Treatment of Sewage.—J. C. S. Beynon, A.M.I.C.E.
Irrigation in Egypt and in South Africa.—F. A. Hurley.
Water Rating.—G. W. Herdman, M.A., M.I.C.E.
Farm Irrigation in the Transvaal.—C. D. H. Braine, A.M.I.C.E.
Power Generation and Distribution.—R. A. Dawbarn.
Irrigation and Inter-Colonial Co-Operation.—W. L. Strange.
Theoretical Investigations regarding Ferro-Concrete.—H. Kestner.

FRIDAY, JULY 13TH.

Important Insect Pests of the Year.—C. W. Howard, B.A.
Locust Birds of the Transvaal.—F. Thomson.
Sanitary Science.—J. S. Dunn.
On the Construction of School Buildings.—G. Bernfield.

SECTION D.

TUESDAY, JULY 10TH.

President's Address by Arnold H. Watkins, M.D., M.R.C.S.
Some Population Figures.—J. M. P. Muirhead, F.S.S.
Native Education in its Higher Branches.—K. A. Hobart Houghton, B.A.
Botany as a School Subject.—Dr. S. Schönland, F.L.S., C.M.Z.S.
European Children in South Africa not receiving any School Education.—K. A. Hobart Houghton, B.A.

WEDNESDAY, JULY 11TH.

Agricultural Land Banks and Agricultural Co-operation in Relation to the Requirements of the Transvaal and of South Africa Generally.—J. R. K. Barker.
Climatic Influence upon Character.—J. Abercromby Alexander.
Libraries for Scattered Districts.—Bertram L. Dyer.
Place of Manual Training in South African Education.—Thomas W. Lowden.
Some Causes and Results of the Recent Advance in Psychology.—W. Wybergh.

ANNUAL GENERAL MEETING.

MINUTES OF THE FOURTH ANNUAL GENERAL MEETING OF MEMBERS HELD AT KIMBERLEY, ON THURSDAY, THE 12TH OF JULY, 1906.

Mr. Sidney J. Jennings, in the absence of the President, occupied the Chair, and amongst those present were:—Messrs. R. T. A. Innes, B. L. Dyer, Dr. Potts, F. Cooper, Cazelet, Alpheus Williams, Dr. S. Schönland, Dr. H. M. Chute, Professor L. Crawford, Professor Duerden, Dr. L. Jameson, Pole Evans, Herdman, Greatbach, Arthur H. Reid, Capt. Quentrall, and the Assistant General Secretaries (E. Hope Jones and Fred. Rowland).

The Minutes of the last Annual General Meeting were taken as read, and confirmed.

The Report of the Council, together with the Treasurer's Report and Financial Statement, were read and adopted.

The names of Members elected by the different Centres as representatives on the Council for the year 1906-07 were submitted to the Meeting, and on the motion of Mr. Innes, seconded by Dr. Chute, their election was unanimously confirmed.

On the motion of the Chairman, seconded by Mr. Cazelet, it was unanimously resolved to accept the invitation that had been received for the Association to hold its Fifth Annual Session in Natal; Meetings to be held jointly at Pietermaritzburg and Durban.

With regard to the Meeting in 1908, Dr. Schönland stated that although he was not in a position to extend a definite invitation at present, it might be taken for granted that the Association would be invited to hold its Sixth Annual Meeting in Grahamstown.

At the suggestion of Dr. Lyster Jameson, which received the support of Professor Duerden and many others, Mr. Innes (the Acting Hon. Secretary), agreed to furnish the more important scientific journals in England with copies of any abstracts of papers read at this Meeting with which authors would supply him.

It was unanimously decided to convey the thanks of the Association to:—

1. The Mayor and Mayoress (Mr. and Mrs. Sagar) and the Town Council of Kimberley for their kind reception of the Members of the Association.

2. To the Mayor and Town Council of Kimberley for the use of the Town Hall buildings.

3. To the De Beers Consolidated Mines, Limited, for the kind reception of the Members of the Association, and for the hospitality and facilities granted in connection with the visits to the mines and other points of interest.

4. To the Chairman and Committee of the High Schools, Kimberley, for the use of their rooms so generously placed at the disposal of the Association.

5. To the Chairman and Committee of the Kimberley Club for extending to visiting members the privilege of membership of the Club.

6. To the Committee of the Public Library, Kimberley, for placing their valuable collection of books at the disposal of Members.

7. To the *Diamond Fields Advertiser* for the excellent manner in which the proceedings of this Meeting were reported.

8. To the Chairmen and Members of the various Local Committees for their valuable assistance, more especially to Professor W. M. Wallace, who kindly carried out the arduous duties of Local Honorary Secretary.

9. To the Cape Government, Central South African, Natal Government, Rhodesia, and Beira and Mashonaland Railways, for travelling facilities granted to Members; and to the Cape Government, Rhodesia, Beira and Mashonaland Railways for providing a special train to convey Members to the Victoria Falls at greatly reduced rates.

10. To Mr. Alpheus Williams, Capt. T. Tyson, Messrs. J. J. Christie T. Reunert, W. Newdigate, C. E. Addams, Dr. A. H. Watkins, Messrs. J. R. Grimmer, A. R. Globe, J. T. Appelbe, W. Gasson, E. W. Mowbray, Hercules Simpson, D. W. Greatbach, and J. R. Sutton for financial assistance.

11. To Dr. J. D. F. Gilchrist and Mr. Wm. Cullen, the Honorary General Secretaries, to Mr. Howard Pim, the Honorary General Treasurer, and to Mr. M. Maclachlan for acting as Honorary Auditor to the Association.

12. To all who contributed to the entertainment of the visiting Members, and the success of the Meeting.

Dr. Schönland proposed, and Mr. Innes seconded, a vote of thanks to Mr. Sidney J. Jennings for presiding, also for acting as President during the Session.

The motion was carried unanimously, and Mr. Sidney J. Jennings returned thanks.

OFFICE-BEARERS AND MEMBERS OF COUNCIL FOR 1906-7.

The following are the office bearers and members of Council for the year 1906-07 :—

President :

JAMES HYSLOP, D.S.O., M.B.. C.M.

Vice-Presidents :

Cape Town.

THOS. MUIR, C.M.G., LL.D.. F.R.SS.L. & E.

Grahamstown.

S. SCHÖNLAND, M.A., Ph.D. F.L.S., C.M.Z.S.

Johannesburg.

SIDNEY J. JENNINGS, M.I.M.E.. M.Amer.I.M.E., M.I.M.M.

Pretoria.

J. BURTT-DAVY, F.L.S., F.R.G.S., F.A.A.A.S.

Hon. General Secretaries :

J. D. F. GILCHRIST, M.A., D.Sc., B.Sc., Ph.D., F.L.S., Cape Town.
WILLIAM CULLEN, Johannesburg.

Hon. General Treasurer :

HOWARD PIM, F.C.A., R.P.A.

Assistant General Secretaries :

E. HOPE JONES, P.O. Box 1497, South African Museum Buildings, Cape Town.
(For Cape Colony and Rhodesia.)

FRED. ROWLAND, F.C.I.S., P.O. Box 1183; 5, Corporation Buildings (2nd Floor), Johannesburg.
(For Transvaal, Orange River Colony and Natal.)

Managing Committee of Council:

The PRESIDENT.
The GENERAL TREASURER.
The GENERAL SECRETARIES.
Professor L. CRAWFORD, M.A., D.Sc., F.R.S.E.
Rev. WM. FLINT, D.D.
S. SCHÖNLAND, M.A., Ph.D.
ERNEST WILLIAMS, A.M.I.C.E., M.I.M.M.

Trustees :

The PRESIDENT.
H. M. ARDERNE.
W. T. BUISSINNE.

Past Presidents :

Sir DAVID GILL, K.C.B., LL.D., D.Sc., F.R.S., Hon. F.R.S.E.
Sir CHARLES METCALFE, Bart., M.I.C.E.
THEO. REUNERT, M.I.C.E.
GARDNER F. WILLIAMS, M.A.

Past Hon. Gen. Treasurer :

W. WESTHOFEN, M.I.C.E.

Members of the Council:

Barberton.

C. B. PATTRICK, A.M.I.C.E.

Bloemfontein.

JAMES LYLE, M.A.
HUGH GUNN.

Beira.

J. ABERCROMBY ALEXANDER.

Bulawayo.

FRANKLIN WHITE.

Cape Town.

Prof. J. C. BEATTIE, D.Sc., F.R.S.E.
Prof. L. CRAWFORD, M.A., D.Sc., F.R.S.E.
Prof. P. D. HAHN, M.A., Ph.D.
R. MARLOTH, M.A., Ph.D.
J. M. P. MUIRHEAD, F.S.A.A., F.C.I.S., F.S.S., F.R.S.L.
ALBERT WALSH.
Rev. W. FLINT, D.D.

Durban.

JAS. FLETCHER, A.M.I.C.E.

East London.

GEORGE RATTRAY, M.A., B.Sc.

Ermelo.

CLAUDE D. LUCAS.

Germiston.

Dr. R. STRACHAN.

Kimberley.

ARNOLD H. WATKINS, M.D., M.R.C.S.
ALPHEUS F. WILLIAMS.

King William's Town.

H. M. CHUTE, M.R.C.S., L.R.C.P.

Klerksdorp.

E. H. HOWARD.

Lovedale.

ALEX. W. ROBERTS, D.Sc., F.R.A.S., F.R.S.E.

Port Elizabeth.

THOS. REEVE.

Potchefstroom.

T. W. LOWDEN.

Pretoria.

H. D. BADCOCK, M.A., A.M.I.C.E., M.S.I.
G. W. HERDMAN, M.A., M.I.C.E.
A. M. A. STRUBEN, A.M.I.C.E.

Queenstown.

THOMAS FINDLAY TANNAHILL, M.D., C.M., D.P.H.

Salisbury.

GUY A. K. MARSHALL, F.Z.S., F.E.S.

Simon's Town.

D. MACFARLANE, M.I.C.E.

Witwatersrand (including Johannesburg).

A. R. ASPINALL, M.A.
ANGUS J. BEATON, F.C.S.
W. A. CALDECOTT, B.A. M.I.M.M., F.C.S., M.Am.I.M.E.
GEO. S. CORSTORPHINE, B.Sc., Ph.D., F.G.S.
A. VON DESSAUER, M.E.
G. A. H. DICKSON, A.R.I.B.A.
FRANK FLOWERS, F.R.G.S., F.R.A.S.
R. T. A. INNES, F.R.A.S., F.R.S.E., F.R.M.S.
H. LYSTER JAMESON, M.A., D.Sc., Ph.D.
E. J. LASCHINGER, B.A.Sc.
J. G. LAWN, A.R.S.M., A.M.I.C.E., F.G.S.
Prof. R. A. LEHFELDT, B.A., D.Sc.
E. H. V. MELVILL, A.M.I.C.E.
JAMES MOIR, M.A., D.Sc., F.C.S.
Prof. JOHN ORR, B.Sc., A.M.I.C.E., M.I.M.E.
W. C. C. PAKES, L.R.C.P., M.R.C.S., D.P.H., F.C.S., F.S.I.
ARTHUR H. REID, F.R.I.B.A.
ERNEST WILLIAMS, A.M.I.C.E., M.I.M.M.
J. R. WILLIAMS, M.I.M.M., M.I.M.E., M.Amer.I.M.E.

Local Committees and Local Hon. Secretaries at the various Centres represented on the Council.

Beira.

Local Hon. Secretary.

J. ABERCROMBY ALEXANDER.

Bulawayo.

Local Hon. Secretary.

F. P. MENNELL, F.G.S.

East London.

Local Committee.

HAROLD E. B. BROOKING.
B. H. DODD, M.A.
GEORGE RATTRAY, M.A., B.Sc.
JOHN WOOD.

Local Hon. Secretary.

HAROLD E. B. BROOKING.

Graham's Town.

Local Hon. Secretary.

Prof. J. E. DUERDEN, Ph.D., A.R.C.S.

Kimberley.

Local Committee.

J. J. CHRISTIE.
D. W. GREATBATCH, M.S.A.
D. J. HAARHOFF, J.P., M.L.A.
Capt. T. QUENTRALL, F.G.S., M.I.M.E.
ROBERT C. ROSS.
ARNOLD H. WATKINS, M.D., M.R.C.S.
ALPHEUS F. WILLIAMS.

Local Hon. Secretary.

W. M. WALLACE, Wh.Sc., A.R.C.S., A.M.I.C.E.

King William's Town.

Local Hon. Secretary.

H. MACREADY CHUTE, M.R.C.S. L.R.C.P.

Natal.

Local Committee.

Dr. JAMES HYSLOP, D.S.O.
J. W. SHORES, C.M.G.
JAMES FLETCHER.
Dr. A. MACKENZIE.
C. W. METHVEN.
C. J. MUDIE.
R. à ABABRELTON.

Local Hon. Secretary.

C. W. DOUGLAS DE FENZI, Pietermaritzburg.

Port Elizabeth.

Local Hon. Secretary.

FRED. W. COOPER.

Pretoria.

Local Committee.

A. M. A. STRUBEN (Chairman).
J. ADAMSON.
H. D. BADCOCK, M.A.
J. BURTT DAVY, F.L.S., F.R.G.S.
Dr. J. W. B. GUNNING.
G. W. HERDMAN, M.A.
H. KYNASTON.
W. DE ZWAAN.

Local Hon. Secretary.

Dr. J. W. B. GUNNING.

Queenstown.

Local Committee.

ERNEST E. GALPIN, F.L.S.
ARTHUR HEATLIE, B.A., A.M.I.C.E.
T. F. TANNAHILL, M.D., C.M., D.P.H.
WILLIAM PAISLEY, M.B., B.Ch.

Local Hon. Secretary.

WILLIAM PAISLEY, M.B., B.Ch.

Salisbury.

Local Hon. Secretary.

G. A. K. MARSHALL, F.Z.S., F.E.S.

Simon's Town.

Local Hon. Secretary.

ERNEST W. ATTRIDGE, C.E., F.I.San.E.

REPORT OF THE COUNCIL FOR THE PERIOD FROM 29TH AUGUST, 1905, TO 12TH JULY, 1906.

The Report of the Treasurer for the year ended 30th June, 1906, with financial statements, is appended.

The total membership of the Association on the 30th June, 1906, was 1,322, showing a net increase of 33 for the year. Since that date 21 new members, and 36 Associate members have been elected.

With regard to Grants in Aid of Research, the following report is to be made:—

(*a*) Mr. J. Burtt Davy has handed in an interim report on the progress of the "Annotated Catalogue of the Flowering Plants and Ferns known to occur in the Transvaal."

(*b*) Mr. R. T. A. Innes, to whom a grant of £25 was made in aid of the work of preparing tables of the Barometric Pressures over South Africa and adjacent regions, has submitted the complete tables of his results, which are printed in this Report.

(*c*) During the past year a grant of £100 was made to Dr. Alexander W. Roberts, of Lovedale, to aid him in his work on Variable Stars. Dr. Roberts has undertaken to have all his observations reduced and ready for the printer within twelve months from the date of the payment of the grant. Owing to Dr. Roberts' absence in Europe, it has not been possible to obtain a report on the progress of his work for this meeting.

(*a*) Dr. J. D. F. Gilchrist was also granted a sum of £100, with a promise of a further £50 during the current year, to aid in the investigations of the Fresh Water Fishes of South Africa, including those of the Zambesi. The Zoological Section of the British Association has agreed to recommend a grant of £50 from its funds for the purpose of assisting Dr. Gilchrist in these researches. A preliminary report has been received from Dr. Gilchrist.

The Report of the Meeting of the British Association in South Africa last year has been published, and in accordance with an agreement made with the British Association, your Council has purchased at cost price a supply of these volumes, and Life Members and all those who were elected Members before the 30th

June, 1905, and have paid subscriptions for the two years ended 30th June, 1906, have been presented with a copy.

In connection with the visit of the British Association to South Africa, a Committee of Members of the South African Association was formed at Johannesburg for the purpose of publishing the papers read before the British Association in Cape Town and Johannesburg. The Committee received a guarantee from the Transvaal Government to pay £400 towards the cost of printing. Copies of the majority of the papers contributed were obtained, and under the editorship of Mr. H. T. Montague Bell, the matter has been incorporated into four volumes, which are now in the press in England. The volumes, which will prove of great interest to scientific men in South Africa and elsewhere, are being published at a subscription price of £2 2s. per set.

In commemoration of the visit of the British Association to South Africa, a fund was raised under the initiation of the President of the British Association, for the endowment of a Medal and Scholarship or Studentship for South African Students.

I. The Executive Committee of the Medal Fund have submitted the following recommendations to the subscribers in regard to its award:—

(i.) That the Fund, together wth a Die for the Medal be offered to the President and Council of the British Association for transmission to South Africa, subject to the conditions that follow:

(*a*) That the Fund be devoted to the preparation of a Die for a Medal to be struck in Bronze, 2½ inches in diameter; and that the balance be invested and the annual income held in trust.

(*b*) That the Medal and income of the Fund be awarded by the South African Association for the Advancement of Science *for achievement and promise in scientific research in South Africa.*

(ii.) That, as far as circumstances admit, the award be made annually.

II. The Council of the British Association has resolved to add the balance (about £800) of the Special South African Fund to the South Africa Medal Fund.

Your Council has unanimously resolved to accept with every gratitude and high appreciation the offer made by the British

Association, and to undertake the administration of the Fund and the award of the Medal, and has submitted to the British Association the names of the following three Trustees:—

The Superintendent-General of Education for the Cape Colony.

The Controller and Auditor-General for the Cape Colony.

The Registrar of the University of the Cape of Good Hope.

As notified in the circulars issued on the 27th January, 1905, and 20th June, 1906, the Council has accepted with many thanks the offer from Mr. E. B. Sargant to pay the sum of £25 for the best essay on "The best means of preserving the traditions and customs of the various South African Native Races in a form available for future Scentific Research." Members and Associates who wish to compete are reminded that papers must be received by the Secretary of the Association by the 1st December next.

An Anthropological Standing Committee consisting of Sir Godfrey Lagden, Dr. S. Schönland, and Mr. von Dessauer, was appointed during the year to consider the preservation of records, histories, etc., of the Native Tribes in South Africa, and the Committee hopes to present at the next Annual Meeting a report on the progress of the work done. £10 has been voted by the Council for expenses incurred, which sum has, however, not yet been utilised.

Mr. T. Reunert has been appointed the convener of an Educational Standing Committee which has in view the collection and collating of statistics relating to education in South Africa. Mr. Reunert is obtaining the support and assistance of the several Education Departments, and hopes to submit a report to the Council during the coming year.

The Witwatersrand Council of Education has decided to make a grant of £500 to this Association for furthering a scheme of University Extension Lectures. The administration of the Fund is left unconditionally in the hands of the Johannesburg Members of the Council, who have thankfully accepted the grant.

WM. CULLEN,

J. D. F. GILCHRIST,

Hon. Secretaries.

12th July, 1906.

REPORT OF THE HONORARY TREASURER FOR THE YEAR ENDING 30TH JUNE, 1906.

I have pleasure in submitting the following Report, together with the Financial Statement, for the year ending the 30th June, 1906.

The Statement shows, that considering the exceptional circumstances of the past year, including as it did the visit of the British Association, and the expenditure inseparable from such an undertaking in South Africa, the Association is in a sound financial position.

From the Revenue Account it will be noticed that the receipts during the year under review are considerably less than those shown in the preceding account. This may be accounted for mainly by the decrease in the members elected with the consequent decrease in the amounts received from Entrance Fees and Life Membership subscriptions, and the large number of subscriptions which were paid in advance last year, which somewhat abnormally increased the receipts as shown in the previous year's accounts.

The Expenditure during the year just completed, on the other hand, shows a considerable increase over that of the preceding year, due to the visit of the British Association, necessitating a total payment of £920 to that body, as well as increasing the General Expenses, etc., besides an increase in Grants for scientific research of £120; and the printing of the Report for 1905, which in former years has been borne by subscriptions generously given for that purpose.

The Balance Sheet shows that your liabilities are amply covered by your assets, there remaining in the Bank after their payment a sum of £174 19s. 9d., from which will have to be met the expenses of this (Kimberley) Meeting. It will be noticed that nothing has been taken into account for the amount of subscriptions outstanding in arrear which amount to £482, nor has any value been placed upon the volumes of Proceedings (volumes 1 and 2) of which there is a good stock on hand.

The Endowment Fund account, which is credited with all receipts from Entrance Fees and Life Membership subscriptions, now stands at £819, of which amount £700 has been placed by your Trustees on fixed deposit at 4½ per cent. per annum. The interest on this sum will be included annually in the Revenue of the Association in accordance with Section 11 (*b*) of the Constitution.

Assuming that the Members of the Association pay their subscriptions during the coming year, as they have done in the past, I believe it will be possible for the Association at its next Annual General Meeting, to largely increase its grants for scientific research, and thus forward in a very practical way the aims and objects for which it has been founded.

The total Membership of the Association is 1,322, showing a net increase of 33 since the last Report was submitted.

These figures show that taking the population of the country into account, there is ample scope for bringing the Association more prominently before the people of South Africa, and in this manner increasing their interest in the advancement of science.

30th June, 1906. HOWARD PIM, *Hon. Treasurer.*

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

BALANCE SHEET: 30TH JUNE, 1906.

LIABILITIES.

To Subscriptions paid in advance ...		£19 0 0
„ Mr. Sargant's Prize		25 0 0
„ To Sundry Creditors: Small a/cs. outstanding	£32 12 6	
„ British Association for 1905 Report	420 0 0	
„ Subscriptions paid for Sets B.A. Proceedings, less expenses ...	481 1 6	
		933 14 0
„ Endowment Fund A/c.: Balance 30th June, 1905	701 0 0	
„ Received to 30th June, 1906, Entrance Fees	98 0 0	
„ Received to 30th June, 1906, Life Members' Subscriptions ...	20 0 0	
		819 0 0
„ Revenue Account: Balance at June 30th, 1905—Cape Town ...	539 17 1	
Johannesburg...	814 2 0	
	£1,353 19 1	
Less Balance from Revenue A/c. 30th June, 1906	1,160 19 4	
		192 19 9
		£1,989 13 9

ASSETS.

By Investment of Endowment Fund Account: Amount invested (Fixed Deposit) @ 4¼ % ...		£700 0 0
„ Office Furniture: Cape Town and Johannesburg		38 0 0
„ Cash at Bank: Cape Town ...	£88 8 2	
„ „ Johannesburg ...	1,163 5 7	
		1,251 13 9
		£1,989 13 9

I have examined the above Balance Sheet, compared the same with the Books and Vouchers, and hereby certify that it correctly sets forth the position of the Association as at 30th June, 1906, as shown by the Books.

Johannesburg, 7th July, 1906.

M. W. MACLACHLAN, Chartered Accountant, Hon. Auditor.

HOWARD PIM, Hon. Treasurer.

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

REVENUE ACCOUNT FOR THE YEAR ENDING 30TH JUNE, 1906.

EXPENDITURE.

To General Expenses (postages, wires, sundries, etc.)	£130 0 6	
,, Printing and Stationery (including 1905 Report)	217 17 10	
,, Salaries	225 0 0	
,, Branch Expenses	4 14 0	
,, Expenses Kimberley Meeting (preliminary)	11 1 6	
,, Depreciation on Furniture ...	12 12 0	
		£601 5 10
,, Grants for Research		200 0 0
,, Editorial Fees: 1904 Proceedings		50 0 0
,, British Association: Grant, S.A. Meeting	500 0 0	
,, British Association: For 1905 Reports	420 0 0	
		920 0 0
		£1,771 5 10

REVENUE.

By Annual Subscriptions received, 1905-6	£389 0 0	
,, Arrears	157 0 0	
,, Associate Fees: Kimberley Meeting	6 15 0	
		£552 15 0
,, Interest on Fixed Deposit ...		31 10 0
,, Sales of Proceedings, Vols. 1 & 2	8 1 6	
,, Sales of British Association Handbook	18 0 0	
		26 1 6
,, Balance: Excess of Expenditure over Revenue		1,160 19 4
		£1,771 5 10

Johannesburg, 7th July, 1906.

Audited and found correct.

M. W. MACLACHLAN, Chartered Accountant } Hon. Auditor.

LIST OF MEMBERS AS AT 30TH JUNE, 1906.

* Indicates Foundation Members (30th June, 1902).
† Indicates Life Members.

Members are requested to notify the Assistant General Secretaries of any changes in address, or additions which may be necessary, as soon as possible.

†Ababrelton, Robert à, F.R.G.S., F.R.C.I., F.R.E.S., F.S.S., P.O. Box 322, Pietermaritzburg, Natal.
*Aburrow, Charles, P.O. Box 534, Johannesburg.
Acheson, Cyrus H., 1, Highfield Terrace, Doornfontein, Johannesburg.
*Ackermann, A. W., Assoc.M.Inst.C.E., M.S.I., M.C.M.E., c/o A. S. E. Ackermann, Esq., 47, Victoria Street, London, S.W.
Adams, A. E., P.O. Box 644, Johannesburg.
Adams, John Franklin, F.R.A.S., Mervel Hill, Godalming, England.
Adamson, J. E., Education Department, Pretoria.
*Adamson, William, P.O. Box 426, Cape Town.
Addams, C. E., Chief Surveyor, De Beers Consolidated Mines, Ltd., Kimberley, Cape Colony.
Addison, William Henry, c/o Messrs. Mosenthal & Co., Kimberley, Cape Colony.
Aiken, Alex., P.O. Box 2636, Johannesburg.
Aiken, David Chalmers, J.P., P.O. Batstone, Lower Umzimkulu, Natal.
Ainge, E.M., P.O. Box 6674, Johannesburg.
Ainslie, George, Kiaora, Sunny Brae Estate, Newlands, near Cape Town.
Ainsworth, Herbert, P.O. Box 1553, Johannesburg.
Aitken, Miss E., M.A., Girls' High School, Pretoria.
Albrecht, John August, Assoc.M.I.Mech.E., P.O. Box 1361, Cape Town.
Albu, George, The Turrets, Doornfontein, P.O. Box 1242, Johannesburg.
Alexander, J. Abercromby, Mozambique Company, Beira, Portuguese East Africa.
Allen, C. L. R., P.O. Box 69, Klerksdorp, Transvaal.
Alston, R. A., Glencairn G.M. Co., Limited, P.O. Box 191, Germiston, Transvaal.
Altenroxel, H. S., Tyaneen Government Estate, Krobbyfontein, P.O. Haenertsburg, Transvaal.
Amphlett, George Thomas, Standard Bank of South Africa, Ltd., Cape Town.
Anderson, Alfred Jasper, M.A., M.B.Oxon, D.P.H.Camb., M.R.C.S. Lond., City Hall, Cape Town.
Anderson. Wm. Thomas, Rose Deep, Limited, P.O. Box 6, Germiston, Transvaal.

Andrew, D. C., Davaar, Hof Street, Cape Town.
Andrew, Mrs. D. C., Davaar, Hof Street, Cape Town.
*Andrews, G. S. Burt, A.M.I.C.E., M.S.A., P.O. Box 1040, Johannesburg.
Andrew, W. J., P.O. Box 15, Langlaagte, Transvaal.
Appelbe, John T., Mine Survey Dept., De Beers Consolidated Mines, Ltd., Kimberley, Cape Colony.
Armstrong, A. C., c/o Milliken Bros., Engineers, P.O. Box 388, Cape Town.
Armstrong, W., c/o Armstrong & Co., Port Elizabeth, Cape Colony.
Arnold, Dr. F., P.O. Box 356, Pretoria.
Arnot, W. M., P.O. Box 1129, Johannesburg.
Arnott, William, Gas Works, Port Elizabeth, Cape Colony.
Aspinall, A. R., M.A., Parktown School, Wellington Road, Parktown, P.O. Box 403, Johannesburg.
Aspland, C. Hatton, Witwatersrand Deep, Limited, P.O. Box 5, Knights, Transvaal.
Atkinson, Harold W., Erwood, Beckenham, Kent, Eng.
*Attridge, Ernest William, C.E., F.I.San.E., Mount Pleasant, Simon's Town, Cape Colony.
Auret, A. A., P.O. Box 838, Johannesburg.
Austin, Henry B., Government Deeds Office, Bloemfontein, O.R. Colony.
Ayres, G. F., Woodward, Rondebosch, near Cape Town.

Babbs, Arthur Thomas, Memb. Quantity Survrs. Assoc., England. Rhodes Buildings, Cape Town.
Badcock, H. D., A.M.I.C.E., M.A., P.O. Box 440, Pretoria.
Bailey, Abe, P.O. Box 50, Johannesburg.
Bailey, Dr. W. F., Falmouth Villa, Main Road, Sea Point, near Cape Town.
Baily, H. A., P.O. Box 1281, Johannesburg.
Bain, C. A. O., P.O. Box 184, Johannesburg.
*Baker, Herbert, Exploration Buildings, P.O. Box 4959, Johannesburg.
Baldwin, Major J. G., British Vice-Consulate, Lourenço Marques.
Balfour, Dr. Harry H., Colinton, Cleveland, Transvaal.
Balfour, Mrs. H. H., Colinton, Cleveland, Transvaal.
Ball, H. S., P.O. Box 2536, Johannesburg.
Ball, Thomas J., P.O. Box 2536, Johannesburg.
Ball, Mrs. T. J., P.O. Box 2536, Johannesburg.
Balmforth, Rev. Ramsden, Daisy Bank, Upper Camp Street, Cape Town.
*Banham, Charles Proctor, M.Inst.E.E., M.I.Mech.E., Table Bay Harbour Works, Cape Town.
Banks, John, Rietfontein "A," Ltd., P.O. Germiston, Transvaal.
*Barker, J. R. K., P.O. Box 3321, Johannesburg.
*Barnes, J. F. E., C.M.G., Public Works Department, Pietermaritzburg, Natal.

Barnetson, William, P.O. Box 6100, Johannesburg.
Basden, A. E., Lieutenant-Governor's Office, Pretoria.
†Basto, His Excellency Alberto Celestino Ferreira Pinto, Governor of Manica and Sofala Province, Beira, Portuguese East Africa.
Baumann, Dr. E. P., 1, Thrupp's Buildings, Pritchard Street, Johannesburg.
Baxter, William, M.A., South African College School, Cape Town.
Bay, Dr. B., P.O. Box 5513, Johannesburg.
Beal, Colonel Robert, Beira and Mashonaland Railways, Beira, Portuguese East Africa.
Beaton, Angus J., F.C.S., Engineers' Department, C.S.A. Railways, Johannesburg.
*Beattie, Professor J. C., D.Sc., F.R.S.E., South African College Cape Town.
Beck, Dr. J. H. Meiring, The Drostdy, Tulbagh, Cape Colony.
*Becker, H. F., M.D., F.L.S., F.S.A., Die Duvenoek, Graham's Town, Cape Colony.
Beckett, G. William, Coombe Villa, Sunnyside, P.O. Box 424, Pretoria.
Beckmann, A. Eckart, P.O. Box 417, Johannesburg.
Beddy, William Henry, Kimberley Club, Kimberley, Cape Colony.
*Behr, Hans C., Consolidated Gold Fields of South Africa, Limited, P.O. Box 67, Johannesburg.
*Beisly, P. S., P.O. Box 6293, Johannesburg.
Bell, F. W., P.O. Box 5666, Johannesburg.
Bell, H. T. Montague, B.A., North China Herald, Shanghai, China.
Bell, J. W., P.O. Box 4617, Johannesburg.
Bell-John, H., Public Works Department, Pretoria.
Bell, W. Reid, M.I.C.E., F.R.Met.Soc., P.O. Box 2263, Johannesburg.
Bender, Rev. A. P., M.A., Synagogue House, Cape Town.
Benjamin, Miss E., "Evalina," Paul Nel Street, Johannesburg.
Bennington, C. E., Fire Station, Pretoria.
*Bennett, Thomas, M.Inst.C.E., Municipal Offices, Muizenberg, near Cape Town.
Bernfeld, G., P.O. Box 3072, Johannesburg.
*Berry, Hon. Sir William Bisset, Kt., M.A., M.D., M.L.A., Queen's Town, Cape Colony.
Bettington. C. A., P.O. Box 35, Johannesburg.
Beyer, S. W., Beira, Portuguese East Africa.
Beyers, P. M., P.O. Box 1115, Johannesburg.
Beynon, J. C. S., A.M.I.C.E., P.O. Box 2926, Johannesburg.
Biden, Arthur, P.O. Box 3384, Johannesburg.
Bidwell, Dr. C. H., P.O. Box 24, Bloemfontein, O.R. Colony.
Bisset, James, J.P., M.Inst.C.E., Beauleigh, Kenilworth, near Cape Town.
Blackshaw, Geo. N., B.Sc., F.C.S., Agricultural Chemist, Government School of Agriculture, Elsenburg, Mulder's Vlei, Cape Colony.

Blaine, H. F., Bloemfontein, O.R. Colony.
Blaker, W. H., (address wanted).
Blane, George, Durban, Natal.
*Blane, James, P.O. Box 191, Germiston.
Bleloch, W. E., P.O. Box 738, Johannesburg.
Blieden, Dr. M., P.O. Box 5297, Johannesburg.
Blood, Dr. Charles Holcroft, National Bank Buildings, Von Brandis Square, Johannesburg.
Blore, Harold W. J., P.O. Box 31, Johannesburg.
Bloxam, Hugh Charles Loudon, Analyst and Laboratory Manager, Heynes, Mathew & Co., Cape Town.
Bodong, L., Beira, Portuguese East Africa.
Bolton, Sidney A., P.O. Box 512, Durban, Natal.
Bolus, Harry, D.Sc., F.L.S., Sherwood, Kenilworth, near Cape Town.
Bond, W. P., King William's Town, Cape Colony.
*Boulton, H. C., c/o Messrs. Pauling & Co., Ltd., Maramba Depôt, Livingstone, N.W. Rhodesia.
Bourke, Dr. William, New Club, Johannesburg.
Bourne, A. H. J., M.A., Principal, High Schools, Kimberley, Cape Colony.
Bradford, Wager, Langlaagte Deep, Limited, P.O. Box 5, Fordsburg, Transvaal.
Bradley, A. A., P.O. Box, 5, Cleveland, Transvaal.
Bradley, Ben, P.O. Box 2718, Johannesburg.
Bradley, C. K., P.O. Box 1024, Johannesburg.
*Braine, C. Dimond H., A.M.I.C.E., Irrigation Department, Pretoria.
Brakhan, Amandus, P.O. Box 4249, Johannesburg.
Bramley, Harry, P.O. Box 56, Klerksdorp, Transvaal.
Brammer, Charles, Germiston, Transvaal.
Brauer, Karl, P.O. Box 23, Potchefstroom, Transvaal.
Brayshaw, B. W., P.O. Box 171, Johannesburg.
Brearley, F. T., M.I.M.E., Pendennis, Muizenberg, near Cape Town.
Brearley, Mrs. F. T., Pendennis, Muizenberg, near Cape Town.
Brennan, Francis Joseph, Architect, c/o Brennan & Hill, P.O. Box 16, Kimberley, Cape Colony.
Brice, Seward, M.A., LL.D., K.C., Rand Club, Johannesburg.
*Brigham, Alexander Fay, Mining Engineer, De Beers Consolidated Mines, Ltd., Kimberley, Cape Colony.
Brims, Charles R., C.E., New Dock Works, Simon's Town, Cape Colony.
Brincker, J. C. H., P.O. Box 87, Port Elizabeth, Cape Colony.
*Bromley, Robert, C.E., District Inspector, No. 1 District, Public Works Department, Cape Town.
Brooking, Harold E. B., East London, Cape Colony.
*Brooks, Edwin James Dewdney, C.E., Public Works Department, Umtata, Transkei.
Brooks, F. C. Huxley, Frame Street, Middelburg, Transvaal.

Broom, Robert, M.D., C.M., B.Sc., C.M.Z.S., Victoria College, Stellenbosch, Cape Colony.
Brown, Alex. F., P.O. Box 342, Johannesburg.
Brown, F. Leslie, P.O. Box 67, Johannesburg.
Brown, Johnstone, M.B., C.M., P.O. Box 94, Jeppestown, Johannesburg.
Brown, Lionel Clifford, Beyers Kloof, Klapmuts, Cape Colony.
Brown, Mrs. Hannah L., Glen Avon, Somerset East, Cape Colony.
Brown, Professor Alexander, M.A., B.Sc., South African College, Cape Town.
Brown, Walter Bruce, District Engineer, C.G. Railways, Cradock, Cape Colony.
Brown, Wm. M., Fortescue Road, Yeoville, Johannesburg.
Brown, William Nimmo, District Forest Officer, Uitvlught, Mowbray, near Cape Town.
Browne, Rev. W. G., 8, Mortgage Buildings, Pretoria.
Bruun, Andreas Frederick, Standard Bank of S.A., Ltd., P.O. Box 598, Johannesburg.
*Buchan, James, Dist. Engineer, Rhodesia Railways, P.O. Box 422 Bulawayo.
Buckland, John Mortimer, Rand Club, Johannesburg.
Burgess, Herbert Lewis, Jupiter G.M. Co., Ltd., P.O. Jupiter Station, Transvaal.
Burke, Edmund Colpoys Lardner, B.A. Cape, 185, Du Toit's Pan Road, Kimberley, Cape Colony.
Burmester, Arthur P., Burmester's Buildings, Adderley Street, Cape Town.
Burroughs, Herbert John, Morcom Road, Zwartkop Valley, Pietermaritzburg, Natal.
Byden, A. J., Rhodes Buildings, Cape Town.
Byron, Lieut.-Colonel J. J., Westminster Estate, *via* Thaba 'Nchu, Orange River Colony.

Cadenhead, James F., P.O. Box 412, Johannesburg.
*Cairncross, T. W., Colonnade Buildings, Greenmarket Square, Cape Town.
Caldecott, H. S., Rand Club, Johannesburg.
Caldecott, Miss G. M., Walmfried, Bok Street, Johannesburg.
Caldecott, Miss Madeleine Rennie, Walmfried, Bok Street, Johannesburg.
Caldecott, W. A., F.C.S., M.I.M.M., P.O. Box 67, Johannesburg.
*Callen, Thomas, Assoc.M.Inst.C.E., M.S.I., Borough Engineer, Kimberley, Cape Colony.
Calverley, Major E. L., Calverley Hall, Bloemfontein, O.R. Colony.
Calvert, E. Wood, (address wanted).
Camerer, R., P.O. Box 2358, Johannesburg.
Cameron, Duncan, Chamber of Commerce, Beira, Portuguese East Africa.
*†Campbell, Allan McDowell McLeod, C.E., B.A., F.I.Inst., Resident Engineer, Aliwal North, Cape Colony.

Campbell, Charles William Rea, King's Hotel, Fox Street, Johannesburg.
Carpenter, Leonard, Government Observatory, Bellevue East, Johannesburg.
Carper, J. B., P.O. Box 1032, Johannesburg.
Carter, H. J., Government School, P.O. Box 63, Roodepoort, Transvaal.
Carter, Mrs. W. J. Becher, Alexandra Club, Burg Street, Cape Town.
Carter, Thomas Lane, P.O. Box 25, Luipaardsvlei, Transvaal.
Cartwright, John Dean, M.L.A., Beau Soleil, Salisbury Road, Wynberg, near Cape Town.
Cashmore, M., M.P.S., 1, Warwick Crescent, Maida Hill, London.
Castro, Alvaro de Saldahna e., Biera, Portuguese East Africa.
*Catlin, R.M., B.Sc., C.E., E.M., Franklin Furnace, New Jersey, U.S. America.
Cazalet, Percy, Nourse Mines, Limited, P.O. Box 32, Denver, Transvaal.
Chaubaud, John Anthony, Attorney-at-Law, Wyndomayne, Park Drive, Port Elizabeth, Cape Colony.
Chalmers, J. A., M.E., P.O. Box 226, Bulawayo, Rhodesia.
†Champion, Ivor Edward, P.O. Roberts Heights, Pretoria.
Chaplin, Frederick George, Perie Trout Hatchery, near King William's Town, Cape Colony.
*Chapman, Arthur Dodwell, Assoc.M.Inst.C.E., District Engineer, Cape Government Railways, Port Elizabeth, Cape Colony.
*Charlton-Perkins, W. T., Highclere, Brownlow Road, Tamboer's Kloof, Cape Town.
Chatterton, Guy, Dental Surgeon, East London, Cape Colony.
Chester-Master, Lieut.-Col. R., Resident Commissioner and Commandant-General in Southern Rhodesia, The Residency, Salisbury, Rhodesia.
Chidell, Charles Arnold, Sevington, Parktown, Johannesburg.
Chidell, Mrs., Sevington, Parktown, Johannesburg.
Child, Harry Shaw, M.I.Mech.E., Uitenhage, Cape Colony.
Chilton, James, P.O. Box 4687, Johannesburg.
Christie, James John, Civil Commissioner, Kimberley, Cape Colony.
Chute, Henry Macready, M.R.C.S., L.R.C.P.Edin., Ayliff Street, King William's Town, Cape Colony.
Cinnamon, Isaac, P.O. Box 7, Pretoria.
Clark, John, M.A., LL.D., Professor of Eng. Lang. and Literature, South African College, Cape Town.
*Clarke, Rev. W. E. C., M.A., P.O. Box 1144, Pretoria.
Clarkson, Hugh, New Rietfontein Estates, Limited, P.O. Germiston, Transvaal.
Clarkson, R., Rietfontein "A," Limited, P.O. Germiston, Transvaal.
*Clarkson, W. J., P.O. Box 149, Johannesburg.
*Cleeve-Edwards, Walter, Assoc.M.Inst.C.E., M.I.Mech.E., F.C.S., Public Works Department, Cape Town.

Clementson, Rev. William Lawson, M.A.Cape, B.D.Durham, St. Mark's Rectory, Cape Town.
Cliffe, Frederic, New Club, Johannesburg.
Coaton, Arthur Allen, Highfield Terrace, Doornfontein, P.O. Box 1176, Johannesburg.
Cobb, Francis Hill, M.I.E.S., (address wanted).
*Cobley, W. H., M.I.C.E., I.S.O., Natal Government Railways, Pietermaritzburg, Natal.
*Cochrane, Louis H., District Engineer, Cape Government Railways, Naauwpoort Junction, Cape Colony.
Cohen, Walter P., P.O. Box 68, Johannesburg.
Colenbrander, W. M., P.O. Box 84, Vryheid, Transvaal.
*Colley, John, M.I.Mech.E., Certificated Colliery Manager, Indwe Mines, Cape Colony.
*Collie, James V. B., F.I.S.E., R.P.C., P.O. Box 342, Cape Town.
Collins, Ernest A. E., 66, Pritchard Street, Johannesburg.
Collins, Louis N. B., P.O. Box 723, Johannesburg.
Collins, M. R., P.O. Box 557, Pretoria.
*Colson, William Henry, C.E., c/o M. Kendall, Esq., Tulse Hill, Streatham, S.W., England.
*Connolly, R. M., P.O. Box 862, Johannesburg.
Connolly, Mrs. R. M., P.O. Box 862, Johannesburg.
Connolly, S. M., Judges' Chambers, Pretoria.
Cook, Arthur, The Foreland, Avenue Protea, Sea Point, near Cape Town.
Cook, Mrs. Arthur, The Foreland, Avenue Protea, Sea Point, near Cape Town.
Cook, John, City Engineer, Cape Town.
Cooke, Herbert S., M.A., P.O. Box 1086, Pretoria.
Cooper, Arnold W., J.P., F.R.M.S., Richmond, Natal.
Cooper, Fred W., Librarian, Public Library, Port Elizabeth, Cape Colony.
Corbalis, Captain James, Talana, Plumstead, near Cape Town.
Cordeaux, Herbert J. C., Architect, East London, Cape Colony.
*Corner, Charles, M.Inst.C.E., Assoc.M.Am.Soc.C.E., Resident Engineer, Rhodesia Railways, Bulawayo, Rhodesia.
*Corstorphine, G. S., Ph.D., B.Sc., P.O. Box 67, Johannesburg.
*Cory, Professor George Edward, M.A., Rhodes University College, Graham's Town, Cape Colony.
*Coster, William Wallace, Assoc.M.I.Mech.E., 109, Long Street, Cape Town.
Coulson, Robert Pickering, P.O. Box 4678, Johannesburg.
Coupé, Robert Martyn, c/o Land Survey Department, De Beers Consolidated Mines, Limited, Kimberley, Cape Colony.
Couper, Lindley Clyde, Equitable Life Assurance Society, P.O. Box 250, Cape Town.
Court, S. E., P.O. Box 1049, Johannesburg.
†Coutts, John Morton Sim, M.D.Lond., D.P.H.Camb., M.R.C.S. Eng., L.R.C.P.Lond., etc., 88, Highbury New Park, London, N., England.

Coverton, R. H., M.I.E.E., A.M.I.C.E., P.O. Box 1049, Johannesburg.

Cox, Douglas Brenton, Natal Government Railways, Pietermaritzburg, Natal.

*Cox, Walter Hubert, Royal Observatory, near Cape Town.

Craib, David, M.A., Education Department, Cape Town.

*Craig, William, Assoc.M.Inst.C.E., Public Works Department, Cape Town.

*Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E., South African College, Cape Town.

Creswell, F. H. P., A.R.S.M., A.M.I.C.E., P.O. Box 402, Johannesburg.

Crofts, J. Murray, Johannesburg College, Berea, Johannesburg.

Croghan, Edward H., P.O. Box 149, Johannesburg.

Crosse, Andrew F., P.O. Box 598, Johannesburg.

Crowder, T. Herbert, Natal Government Railways, Pietermaritzburg, Natal.

Cullen, William, Dynamite Factory, Modderfontein, Transvaal.

Cullen, Mrs. W., Dynamite Factory, Modderfontein, Transvaal.

Curlewis, Hon. Justice J. C., Judges' Chambers, P.O. Box 477, Johannesburg.

Curnow, Robert, Nigel G.M. Co., Limited, Nigel, Transvaal.

Currie, Dr. H. B., P.O. Box 1102, Johannesburg.

Currie, Dr. O. J., M.B., M.R.C.S., 24, Longmarket Street, Pietermaritzburg, Natal.

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Dubois, Mrs. Raymond (address wanted).
Duft, Gustav, Kaiserkicher Bergrath, Windhoek, German S.W. Africa, *via* Swakopmund.
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Hatchard, John George, F.R.A.S., P.O. Box 508, Bloemfontein, O.R. Colony.
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Bowden, T., Kimberley, Cape Colony.
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Green, H. R., Sea Point, near Cape Town.
Green, Mrs. H. R., Sea Point, near Cape Town.
Green, Miss Ivy, Sea Point, near Cape Town.
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Lawrence, Mrs. Brown, Mount Nelson Hotel, Cape Town.
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Waring, Miss M. E., Pretoria.
Willis, Miss L., Firholme, Yeoville, Johannesburg.

LIST OF INDIVIDUALS, SOCIETIES, PUBLIC INSTITUTIONS, ETC., PRESENTED WITH A COPY OF THE ANNUAL REPORT.

His Excellency The High Commissioner.

Governors :—

- Cape Colony, His Excellency The Hon. Sir Walter Hely-Hutchinson, G.C.M.G.
- Transvaal, His Excellency The Hon. Sir Arthur Lawley, K.C.M.G.
- Natal, His Excellency Col. Sir Henry E. McCallum, K.C.M.G., R.E., A.D.C.
- Orange River Colony, Major Sir H. J. Goold-Adams, K.C.M.G., C.B.

Sir W. H. Milton, C.M.G., Administrator of Rhodesia.
Herbert Cecil Sloley, Resident Commissioner, Basutoland.
Lt.-Col. H. L. Gallway, C.M.G., D.S.O., Governor and Commander-in-Chief of St. Helena.
The German South-West Africa Government.
The Portuguese Government, Delagoa Bay.
His Excellency The Governor of the District of Lourenco Marques.
The Admiral Commanding the Fleet, Simon's Town.
The Commander of the Forces in South Africa.
Government of the Cape Colony.
Government of the Transvaal.
Government of Natal.
Government of the Orange River Colony.
Government of Rhodesia.

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Cape Times, Cape Town.
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The Leader, Johannesburg.
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The Pretoria News, Pretoria.
The Volksstem, Pretoria.

Orange River Colony :—

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LONDON.

Nature.
The Times.
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The Academy.

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The Royal Observatory.
S.A. Philosophical Society, Cape Town.
Eastern Province Naturalists' Society, Port Elizabeth.
The Athenæum, Kimberley.

Transvaal :—

The Transvaal Philosophical Society.
The Chamber of Mines.

Orange River Colony :—

Bloemfontein Philosophical Society.

Rhodesia :—

Scientific Association, Bulawayo.

MUSEUMS.

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Albany Museum, Grahamstown.
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Port Elizabeth.

Australia :—

Australian Association for the Advancement of Science.

Adelaide :

Royal Society of South Australia.

Brisbane :

Royal Society of Queensland.

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Sydney:
Geological Survey, New South Wales.
Royal Society of New South Wales.

Austria:—
Vienna:
Kaiserliche Akademie der Wissenschaften.

Belgium:—
Brussels:
Académie Royale des Sciences.

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Royal Society of Canada.
Toronto:
Canadian Institute.

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Copenhagen:
Kongelige Danske Videnskabernes Selskab.

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Association Francais pour l'Advancement des Sciences.
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Königliche Preussische Akademie der Wissenschaften.
Verein der Naturforscher und Aerzte.
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Königliche Bayerische Akademie der Wissenschaften.

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Calcutta :
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Koninklijke Akademie van Wetenschappen.
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Académie Impériale des Sciences.

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Philosophical Society.
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Madrid .
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Stockholm :
Kongliga Svenska Vetenskaps-Akademie.

Switzerland :—
Geneva :
Société de Physique et d'Histoire Naturelle de Genèv
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Naturforschende Gesellschaft.
International Chemical Society.

Tasmania :—
Hobart :
Royal Society of Tasmania.

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  - Academy of Sciences.
  - Field Columbian Museum.
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- Philadelphia:
  - American Philosophical Society.
- St. Louis:
  - Academy of Science.
- Salem (Mass.):
  - American Association for the Advancement of Science.
- San Francisco:
  - California Academy of Sciences.
- Washington:
  - National Academy of Science.
  - Smithsonian Institution.
  - United States National Museum.

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